PAPERS AND PROCEEDINGS OF

THE ROYAL SOCIETY OF TASMANIA

Edited by M.R. Banks and S.J. Smith

and Published by the Society

Hobart

Tasmania

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30 JUNE 1994

VOLUME 128

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VOLUME 128

ISSN 0080-4703

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Her Majesty the Queen

President
His Excellency the Governor of Tasmania
General Sir Phillip Bennett, AC, KBE, DSO

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Mr J.T.W. Hayton
(on leave from 5 August 1993)

Dr M.R. Banks AM

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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA

Volume 128

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Publication of this volume was generously supported by the Government of Tasmania and the University of Tasmania.

ROYAL SOCIETY OF TASMANIA
Annual Report for the Year 1993

The Council has the honour to present to members the following report on the activities of the Society during the year.

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Honorary Assistant Editor
Dr S.J. Smith

President

His Excellency General Sir Phillip Bennett took the chair as President of the Society at the Annual General Meeting. He presided over a number of significant events during the year, which included the Sesquicentenary Dinner at Drysdale House, 24 March 1993, to launch the Society's special publication of James Backhouse Walker's *Walk to the West* edited by Professor D.M. Stoddart; the Sesquicentenary Celebrations held by the Northern Branch on 6 August 1993; and the presentation of the Royal Society of Tasmania Medal, the R.M.Johnston Medal and the Clive Lord Medal at a Special Meeting, 19 July 1993.

His Excellency hosted a reception at Government House for members of the Society on 14 October (the anniversary of the first meeting) to celebrate the Sesquicentenary.

Deaths

The deaths of the following members are recorded with regret:

Mr E. C. Gifford AM
Sir George Crawford KB

Obituaries

Edwin Chester Gifford AM
died 2 August 1993 in Hobart

A member since 1960, Mr Gifford, former Chief Manager of the Commonwealth Bank, had many philanthropic and cultural interests. He was the Society's Junior Vice President, 1970, Senior Vice President, 1971, and a Councillor from 1968–69 and from 1972–74 inclusive.

Sir George Crawford KB
died 22 October 1993 in Launceston

Sir George was member of the Society for 54 years from 1939. He made significant contributions to the Society in his various roles as Chairman of the Northern Branch, Council Member of the Northern Branch, representative of that Branch on the Cradle Mountain Lake St Clair National Park Board, and with Frank Ellis and Hawley Stancombe, he edited the Wedge Diaries for publication by the Society

Honours and Awards

The Society congratulates the following members on honours received:

Dr Shirley Jeffrey AM
Mrs Mary Cameron AM
Mr John Kennedy OAM

Membership

The membership is 470, a increase of 59 (or 14.3%) over the previous year, and is made up as follows:

	Southern	Northern	Total
Honorary Life Members	5	2	7
Life Members	22	11	33
Ordinary Members receiving *Papers and Proceedings*	249	52	301
Ordinary Members not receiving *Papers and Proceedings*	63	41	104
Associate Members	16	9	25
	355	115	470

Council Meetings

The Council met six times during the year and in addition held a special corporate planning session with Management Consultant and Royal Society member, Bryce McNair on 7 October 1993.

Corporate Plan
Issues considered by the Council members attending included defining the Society's role, function or mission, and its relevance to to-day's world. A vision for the future, the clarification of objectives, and an assessment of the Society's strengths and weaknesses, threats and opportunities have provided options from which the Council can develop an action plan outlining the future direction, development and promotion of the Society for consideration by the membership in the coming year.

Future Directions Questionnaire
Early in 1993 a questionnaire was circulated to assess members' views and attitudes. There were some 140 replies. The Society was perceived as worthwhile and having some considerable achievements in the past. Issues to be addressed included improving the condition of the Royal Society room and the range of topics addressed at the monthly meetings. Council has noted these responses in its planning throughout the year.

Sesquicentennial of the Society

The Society's sesquicentennial in 1993 was marked by three main events, the earliest being the publication of *Walk to the West.* Written by James Backhouse Walker, it is an account of a journey by a party of explorers, mostly Royal Society members, from Hobart to Waratah in 1887.

This account was edited by Professor D.M. Stoddart and illustrated with reproductions of paintings and sketches by the Tasmanian artist, W.C. Piguenit, who was, for some part of the journey, one of the party. The book was designed, printed and bound in Tasmania and won two printing industry (PICA) awards including the Gold printing award for all categories of printing work.

Donations from learned societies around the world, the Australian business community, the Federal and State Governments, the City of Hobart and the University of Tasmania, together with advance orders for over 300 copies assured the financial viability of the project. The book was launched by the President at a well-attended dinner at Drysdale House on 24 March 1993.

The Northern Branch celebrated the Sesquicentennial with a dinner, attended by the President and Lady Bennett, on 6 August, at the Queen Victoria Museum and Art Gallery, Launceston. In an after-dinner speech, Dr Banks outlined the history of the Society.

The anniversary of the first meeting of the Society was marked by a special reception for members given by the President and Lady Bennett at Government House. It was a memorable function and very well attended.

Grants to the Society

The Council received a general grant from the Tasmanian Government, through Arts Tasmania, of $2000 towards the Society's administration and promotion, and a special grant from the Tasmanian Government of $3000 towards the Society's publication program.

The University of Tasmania has provided an annual subvention of $3000 towards the publication costs of the *Papers and Proceedings* of the Royal Society of Tasmania.

Library

The year under review has been one of continued progress and consolidation of projects begun in the previous two years.

The recatalogued and reclassified collection continues to grow as material is transferred from the older sequences. Several programs are under way to identify titles for which University cataloguing data are available, and the fairly easy task of transferring this material to the new sequences is continuing — mostly in cases where the older records are inadequate. To facilitate this program, the card shelf-list sequences are being checked against the data-base and notes made for titles which are candidates for easy transfer.

The consolidation of various sequences of valuable material is also being undertaken in conjunction with the re-cataloguing, and such material will eventually be filed in one "Rare" sequence over the two rooms allocated for such storage. The transfer to the open shelves of some less vulnerable but now electronically controlled items will allow for a consultation table in one of these rooms, when less shelving will be necessary.

The Couchman collection, donated to the Library in 1992, was completely integrated during the year and formed a significant part of the newer collection. Apart from this donation, the cataloguing backlog which has been part of the Library's recent history has been eliminated.

During the year a review of binding was undertaken and annual requirements submitted as part of the University Library Survey, and binding requirements of the Royal Society will be considered when final allocations are made during 1994. A clean-up of the sample cases was also completed during the year, with only the cases for titles still requiring binding being retained. Overall, 181 volumes were bound during the year.

Staffing for the Library remained the same, with Graeme Rayner, the University's Collection Development and Special Collections Librarian, continuing as the Royal Society's Librarian. Clerical help was again provided by Mrs Carol Freeman with additional help for five hours each week from Mrs Emilia Ward.

Towards the end of the year the Librarian moved to accommodation elsewhere in the building and Mrs Freeman moved her operations into the office area. This move has created additional Library space for study and display purposes, together with additional shelving space for the expanding recatalogued collections.

The Library was painted throughout the year — as part of the total repainting of public areas in the Morris Miller building. Minimal disruption to users and staff was achieved during this time. The weeding program is continuing, though on a reduced scale, and it is planned to offer weeded items for sale, initially to members and subsequently through the University Library Book sale.

During the year, all non-file copies of the *Papers and Proceedings* were returned to the Museum for storage. The lack of Library involvement in the distribution of *Papers and Proceedings* — other than the exchange copies — had removed the necessity for any additional copies of the *Papers and Proceedings* at the Library.

Exchange copies of Volume 127 of *Papers and Proceedings* were mailed to exchange partners during November/ December.

Statistics for 1993 are as follows:

Binding	181 volumes
Visitors	404
Inter-library loans	34
In-house consultations	177
Serial loans	63
Inter-campus loans	4

Publications

Volume 127 of the *Papers and Proceedings* was published in October. In addition to the annual report for 1992, it contained ten papers totalling 66 pages. Nineteen authors contributed, most from Tasmania but five from overseas. Topics ranged widely — history, botany and mammals — but most concerned various aspects of ecology, modern and ancient.

Tasmanian Wilderness — World Heritage Values, the volume of up-dated papers delivered at symposium in late 1990 was published in November and jointly launched by the Hon. Duncan Kerr MHR, Federal Minister for Justice and the Hon. John Cleary MHA, Minister for Lands and Environment on 7 December.

Mrs Alison Jones was the expert sub-editor and Mrs June Pongratz the skilled typesetter for both publications. Dr M. Banks and Dr S. Smith were the editors, the former with the main responsibility for the *Papers and Proceedings*, the latter for the World Heritage publication.

Lectures

The following lectures were given at General Meetings during the year:

February — "The life and art of W.C . Piguenit" Dr A.V. Brown and Dr C. Johannes

March — "The first fifty years of the Royal Society" Mrs Gillian Winter, Tasmaniana Collection

April — "Atmosphere, weather and the greenhouse effect" Professor Garth Paltridge FAA, Director of the Institute of Antarctic and Southern Ocean Studies, University of Tasmania, and Mr Hugh Hutchinson, Commonwealth Bureau of Meteorology

May — "Forum on Cambodia" Dr R. Rigby, Department of Foreign Affairs and Trade,Mr Sam Malone, AIDAB, and Captain David Clotha, Australian Defence Forces

June — "Sealer sites on Heard Island" Ms Angela McGowan, Archaeologist, Parks and Wildlife Service, Tasmania

June — "Hibernation in the echidna — old views and new data" Dr Stewart Nicol, Physiology Department, University of Tasmania

July — "The Tasmanian Aboriginal community to-day — a continuing culture" Mr Jim Everett, President, Tasmanian Aboriginal Centre

"Indigenous issues in the international arena" Mr Colin Milner, Head of Human Rights and Social Law Unit, Department of Foreign Affairs, Canberra

July — "Simulating how the deep earth works" **Professor David Green**, FRS, FAA, University of Tasmania, **Royal Society Medallist 1993**

August — "Microscopic marine plants: their global role" **Dr Shirley Jeffrey**, AM, FAA, Chief Scientist, CSIRO Division of Fisheries, **R.M. Johnston Memorial Medallist 1993**

September — "The law and morals" His Grace the Archbishop of Hobart, Dr Eric D'Arcy, and Mr Justice Pierre Slicer

October — "Proceedings of a Museum Director" **Mr Don Gregg**, Director, Tasmanian Museum and Art Gallery (1972–91), **Clive Lord Memorial Medallist 1993**

November — Panel Discussion: How old are Tasmanian mountains? Mr D.G. Hannan, Mr S.M. Forsyth, Professor E.A. Colhoun, Mr J.K. Davidson, Professor R. Hill, Dr M.R. Banks (Convenor)
November 22 — "Slide rules and their history" Mr Ralph Rallings, Roads Tasmania

In addition new initiatives were added to the public program: these included a debate sponsored by the Royal Society, 7ZR and 7NT, broadcast on ABC Radio, entitled "That it is the media and not politicians who trivialise politics".

Northern Branch

Branch Council

Chairman	Mrs M Cameron
Vice Chairman	Mr B Chamberlain
Honorary Secretary	Mr C Tassell
Honorary Treasurer	Mr B. Pike
Council Members	Mr J. Kolkert
	Mr A. Schofield
	Mr A. Orr
	Dr M. Temple-Smith
	Mrs G. Moris

The Branch Council met several times during the year.

Meetings and Lectures

March — Annual General Meeting and "Then and now" Mr A. Orr
April — "Aspects of the Tamar River" Sir Ray Ferral
May — "Recent heritage of the Mawson base" Ms E Wishart
June — Members Night
"Bangor quarry" Mr B. Chamberlain
"Measuring unemployment" Mr B. East
"Bungaree, the king without a kingdom" Mrs D. Girvan
"Nuclear fallout for peaceful use" Dr M. Temple-Smith
"There are good bugs too" Mr B. Pike
September — "Toxic blue-green algal blooms in Australian waters" Dr S. Blackburn
October — "Pasture plants and genetic resources for Tasmania" Dr B. Reid
November — "Tasmanian tree frogs" Dr P. Swiatkowski
December — Members Night
"Stephen Cheek" Mr A. Orr
"Electric Cars" Mr J. Kolkert
"Blind Music Students" Mr P. Webb

Excursions and Functions

June — Excursion to Beams Quarry
July — Visit to the Regional Library, Ms J Hollingsworth
August — Sesquicentenary Dinner: History of the Royal Society, Dr M.R. Banks, AM

Nominees to Other Bodies

The Council elected Dr P.G. Quilty and Professor D.M. Stoddart to serve on the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

The period of appointment for the four Trustees appointed by the Governor in Council on the advice of the Minister of Education expired in 1993. Retiring Trustees were Ms Jooles Whittle, Ms Austra Maddox and Mr Jonathan Holmes.

Reappointed was Mr Alan Blow, Chairman, and new appointments were Mrs J. Freeman, Dr Coleman O'Flaherty and Ms J. Taranto.

As part of its Strategic Plan the TMAG adopted the following Mission statement:

> "The mission of the TMAG is to collect, preserve, display, research and interpret the physical evidence and the accompanying intellectual, scientific and social context of the natural and cultural heritage of Tasmania, together with relevant material from beyond the State and from beyond Australia for the benefit of scholars, researchers, visitors and members of the Tasmanian community."

1993 was a year of further consolidation for the Tasmanian Museum and Art Gallery.

The staff restructuring was implemented with the following appointments and resignations:
Dr Kantvilas, was appointed Co-ordinating Curator of Sciences and Head of the Herbarium; Mr Roger Buttermore, was appointed Curator of Invertebrates; Ms Alison Melrose, was appointed Curator of Information Services and Decorative Arts; Dr Christa Johannes retired as Curator–Art to become the part-time Education Co-ordinator; Ms Julia Clark, Curator–Anthropology, resigned in December to take up a position as Head of Exhibitions at the Western Australian Museum; Mr Bill Bleathman was appointed Manager Public Programs and Operations; Mr Tim Knight was transferred to the position of Bursar at Sorell High School.

The Director Museum Services chaired the organising Committee of the very successful national conference held in Hobart, 1–3 December, CAMA 93: *Common Threads : Diverse patterns — Uniting Australia's Museum Associations;* 308 delegates attended. The Director was appointed to the Commonwealth Government's national exhibition touring funding body *Visions Australia*

The concept plan for the strategic development of the TMAG was developed by a Steering Committee in preparation for future public consultation. In March, the Prime Minister announced the Federal Government's intention to negotiate the sale of the the Customs House with the State Government for use by the Museum. An outcome is expected from these deliberations in 1994.

The 1992/3 State Budget provided a grant for recurrent services and staff of $1 897 000. This includes the salaries for 36.88 FTE staff.

The Museum and Art Gallery has made substantial progress in the computerisation of all its records. There are some 19 computers for staff use, including a Macintosh Quadra, scanner and video input capacity for graphic work and desktop publishing.

The International Year of the World's Indigenous Peoples was celebrated with the launching by Jim Everett, President of the Tasmanian Aboriginal Centre, of a set of reproductions of the drawings of Tasmanian Aborigines by Thomas Bock

The Piguenit exhibition was well received in Hobart, Sydney and Perth in 1993.

Other major exhibitions in 1993 organised by TMAG included *Visions of the Frozen South — Artists in Antarctica; Arnhem Land Dreaming — Bark Paintings from Tasmanian Collections; From Village to Vase* in conjunction with the Garden Historical Society; *Translations — Rick Amor, Geoffrey De Groen and David Keeling; Australian Sculpture from the Collection; Contemporary Photography from the Collection; City of Hobart Award for Sculpture; On the Go — women adventurers of the 20s and 30s.*

Travelling exhibitions included *David Strachan Retrospective* from Art Gallery of New South Wales; *Windswept — Classic maritime photography from the Rosenfeld collection* from the National Maritime Museum; *Completing the Picture — Women Painters of the Heidelberg School* from Art Moves; *Skeletons* from Queen Victoria Museum and Art Gallery; *Split Enz,* costumes from the Performing Arts Museum, Melbourne; *Daughters of a Dreaming — Koorie Women,* Museum of Victoria; *Capturing the Orient — Hilda Rix-Nicholas and Ethel Carrick-Fox,* City of Mt Waverley Gallery.

Work continued on the design of *Antarctica Secrets of the Frozen South,* a joint travelling exhibition project with the Museum of Victoria, sponsored by the Australian Antarctic Foundation, due to open in May 1994.

During the calendar year 1993 a total of 111 128 visitors attended the Museum and Art Gallery, an increase of 7% when compared with 104 000 in 1992. This can be attributed to an increasing public profile for the TMAG and the exceptional interest in the Skeletons exhibition from QVMAG.

The number of visitors to the West Coast Pioneers' Memorial Museum in Zeehan was estimated at about 78 000 for 1993, a considerable reduction attributed to the decline in tourism and the recession.

On 2 October 1993, Mr George Smith, Chairman of the West Coast Pioneers Memorial Museum since 1968, died at his home in Zeehan, aged 94. Mr Smith will be sadly missed. It will be difficult to match his dedication to the West Coast Pioneers Memorial Museum and his committment and contribution to the vision for its future development.

Mr J. E. Tomlinson AO was elected by the Council to serve on the Board of Trustees of the Royal Tasmanian Botanical Gardens. Mr Tomlinson reports on the year's activities:

The RTBG has adopted the following mission statement:

"The mission of the RTBG is to maintain a dynamic botanical collection for scientific study, education and conservation which is accessible to meet public aesthetic, passive recreation and tourist values."

Visitors for the 12 months to June 1993 were 294 058, which was slightly down on the previous year.

The Tulip Festival was another successful event. Although planted at the same time, in 1992 the worry was that they would not bloom in time; in 1993 the worry was that they would be finished. However, enough remained to make the usual fine show.

1993 was the 175th anniversary of the gardens and a number of events were held to celebrate this. The major event was a special weekend in March organised by Alderman Darleen Haigh with an active committee. Friday night was a soiree for invited guests, Saturday was a Victorian garden party with music and entertainment and Sunday was a family fun-day. A number wore period costumes to add to the colour.

The Second International Congress on Education in Botanic Gardens was held in Hobart from 3–8 May with 100 delegates from 35 different countries. The RTBG played an active role.

The Australian Network for Plant Conservation held its first conference in Hobart, 5–8 December, hosted by the RTBG.

Zootango Theatre again held performances in the Gardens — *Alice in Wonderland* and *As You Like It*

Mrs Dorothy Baker retired in June after being trustee for 26 years and Alderman Darlene Haigh resigned in November. Neither have yet been replaced

Twenty months after the untimely death of our superintendent, a Director was finally appointed. Dr David Bedford took up his appointment in October to the delight of Jim Cane, who has done a sterling job in the intervening months in addition to his other duties. David comes with a wealth of experience, having just completed 13 years with the Royal Botanic Gardens of Sydney. He is settling in quickly and coming to grips with the needs of the gardens. We wish him and his family a long and happy stay in Tasmania.

Acknowledgements

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, Arts Tasmania, the Tasmanian Museum and Art Gallery, and the Queen Victoria Museum and Art Gallery are specially thanked for their support and cooperation.

The Society is indebted to our Senior Vice-President, Mr John Hayton, for his very active and innovative leadership. As a consequence of his appointment to a diplomatic post, he departed Tasmania in August for a three-year term in New York. His drive, ideas and activities have invigorated the society.

It was with great regret that it was learned that our Honorary Treasurer for more than a decade, Mr Tim Knight, would not be standing for election in 1994. His services to the Society have been very considerable and he has helped greatly in many ways outside his duties as Treasurer. His support of the Society is greatly appreciated.

We are grateful for the dedicated help given by members of the Council during the year.

M.R. Banks — A/Senior Vice President

P.N. Sabine — Honorary Secretary

February 1994

ROYAL SOCIETY OF TASMANIA
Statement of receipts and payments for the year ending 31 December 1993

Accumulation Account

Balance 1 January 1993			96 163.68
Add	Increased valuation of publications		4 892.30
			101 055.95
Deduct	Decreased cash at bank	33 166.56	
	Net increase in advance subscriptions	151.00	
	Net transfer to Trust Funds	728.46	34 046.02
Balance 31 December 1993			$67 009.96

Balance sheet as at 31 December 1993

1992			*1993*
96 164	Accumulated Funds		67 009.96
126	Subscriptions in advance		277.00
	Trust Funds:		
2 295	– Clive Lord Memorial Fund	2 356.49	
4 876	–A.N. Lewis Memorial Fund	5 005.38	
2 315	–Morton Allport Memorial	2 377.17	
886	–A.A. Clark Bequest	909.45	
2 473	–Joseph Milligan Bequest	2 538.51	
3 298	–R.M. Johnston Memorial Fund	3 385.67	
1 359	–Henry Oliver Bequest	1 395.41	
3 176	–W.H. Hudspeth Memorial	3 260.16	
6 738	–Life Membership Fund	6 916.68	28 144.92
$123 706			$95 431.88

Represented by:

33	Cash on hand		33.00
	Cash at bank:		
61 715	–General account	28 393.46	
4 889	–*Papers and Proceedings* account	4 993.50	
1 079	–Clive Lord Memorial Fund	1 099.39	
1 525	–A.N. Lewis Memorial Fund	1 555.53	36 041.88
860	Mortgage Loan		860.00
7 000	Interest bearing deposits		7 000.00
15 000	Library (at valuation for insurance)		15 000.00
26 005	Publications (at selling prices)		30 897.00
5 600	Medals (at selling price)		5 600.00
$123 706			$95 431.88

The Society owns works of art which have been donated over the years and which do not appear on the Balance Sheet. They are all housed in the Tasmanian Museum and Art Gallery and are covered by that organisation's insurance. A catalogue listing these works of art is available to members.

P. Sabine
Honorary Secretary

T.A.H. Knight, B.Bus. CPA
Honorary Treasurer

ROYAL SOCIETY OF TASMANIA
Statement of receipts and payments for the year ending 31 December 1993

General Account

Balance 1 January 1993			61 715.92	
Receipts				
Subscriptions				
268 @$30	8 040.00			
101 @$18	1 818.00			
22 @$12	264.00			
Other years	961.00	11 083.00		
Publication sales		25 628.21		
Interest		1 683.33		
Interest - other		61.25		
Grants		5 000.00		
Donations		335.00		
Book launch		2 989.35		
Postage		10.00		
			46 790.14	
				$108 506.06
Payments				
Printing and stationery		1 594.22		
Postage		1 982.82		
Post box rental		180.00		
Library books and subs		2 233.75		
Telephone		41.20		
Bank duties and charges		74.39		
Attendant fees		998.97		
Secretarial fees		1 500.00		
Northern Branch subsidy		1 500.00		
Insurance		483.56		
Meetings and lectures		417.40		
Medal engraving		36.50		
Publications				
Papers and Proceedings	10 254.38			
Walk to the West	39 367.31			
World Heritage Symposium	15 512.58			
		65 134.27		
Refunds		240.00		
Book launch	3 021.30			
Advertising flyers	674.22	3 695.52		
			80 122.60	
Balance 31 December 1993			28 393.46	
				$108 506.06

ROYAL SOCIETY OF TASMANIA (NORTHERN BRANCH)
Statement of receipts and payments for the year ending 31 December 1993

Receipts			*Payments*		
Subscriptions	72.00		Subscriptions to Hobart	90.00	
Suppers	25.10		Printing and Stationery	165.77	
Grant	1500.00		Theatrette hire	0.00	
Bank interest	2.97		Postage	337.50	
Miscellaneous (dinner)	573.00		Post box	37.00	
		2173.07	Secretarial	201.25	
			Bank charges	4.30	
			Suppers	46.25	
			Sundries	775.00	1657.07
Balance at Trust Bank		0.13–	Balance		515.87
		$2172.94			$2172.94

K-AR DATED PALYNOFLORAS IN TASMANIA 1: EARLY OLIGOCENE, *PROTEACIDITES TUBERCULATUS* ZONE SEDIMENTS, WILMOT DAM, NORTHWESTERN TASMANIA

by M.K. Macphail & R.S. Hill

(with two tables, five plates, three text-figures and an appendix)

Macphail, M.K. & Hill, R.S., 1994 (30:vi): K-Ar dated palynofloras in Tasmania 1: Early Oligocene, *Proteacidites tuberculatus* Zone sediments, Wilmot Dam, northwestern Tasmania. *Pap. Proc. R. Soc. Tasm.* 128: 1–15. ISSN 0080–4703. Department of Geography, University of Newcastle, Newcastle, New South Wales, Australia 2308 (MKM); Department of Plant Science, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001 (RSH).

Tertiary lake sediments at Wilmot Dam, northwestern Tasmania, are dated as Lower *Proteacidites tuberculatus* Zone, based on the palynological zonation developed for the Gippsland Basin in eastern Bass Strait. The age limits of Early–Middle Oligocene for this zone are in excellent agreement with a K/Ar date of 26.7 Ma for basalts capping this deposit. Three new species are described: *Tricolpites stylidioides, Mutisiapollis patersonii* and *Periporopollenites hexaporus*. The first two appear to be the earliest records to date of Stylidiaceae and *Mutisia* (Asteraceae: tribe Mutisieae) respectively.

Key Words: palynofloras, Oligocene, Stylidiaceae, *Mutisia*, Trimeniaceae, Tasmania.

INTRODUCTION

The palynological zonation scheme developed for the Gippsland Basin by Stover & Partridge (1973) has become widely used to date sediments elsewhere in Australia — to the extent that the individual zones, such as the Oligocene–late Early Miocene *Proteacidites tuberculatus* Zone, have become informal Stage names for the Australian Tertiary.

The criteria defining the zone boundaries, however, have had to be adapted from region to region to take account of known or suspected diachronism in the times of first appearance and extinction of zone "index" species. With few exceptions, this reflects variation in environmental forcing factors operating on the local to regional scale (see Macphail *et al.* 1994).

Widespread Tertiary volcanism has allowed a number of palynofloras in eastern Australia to be independently dated using Potassium/Argon (K/Ar), although in most situations this provides only a maximum or minimum age limit (e.g. Owen 1988, Pickett *et al.* 1990, Taylor *et al.* 1990, Macphail *et al.* 1991). Sutherland & Wellman (1986) have reviewed K/Ar dated volcanic rocks in Tasmania. This paper is the first in a series using a K/Ar dated palynoflora to assess the reliability of the Stover & Partridge Gippsland Basin zonation as a method for dating non-marine sediments in Tasmania.

The sequence we analyse comes from the Wilmot Dam site in the Moina area of northwestern Tasmania (fig. 1). Here K/Ar dating confirms not only the *P. tuberculatus* Zone date for a buried channel deposit but also provides independent age control on glaciation of the adjacent upper Forth Valley during the late Paleogene (Macphail *et al.* 1993a). Three new fossil pollen species are described: *Tricolpites stylidioides, Mutisiapollis patersonii* and *Periporopollenites hexaporus* (appendix 1). Three other palynomorphs that may prove to be useful for identifying *P. tuberculatus* Zone palynofloras in Tasmania are illustrated: *Tetrapollis campbellbrownii, Pesavis* sp. cf. *P. tagluensis* and a distinctive but undescribed fungal fruiting body (pl. 1, M–P, see page 7).

GEOLOGICAL SETTING

Moina is located in an area of low, rugged interfluve ridges between the northwestern escarpment of the Central Plateau and Black Bluff Range. The region is geologically complex due to (1) partial stripping of subhorizontal Jurassic dolerites, exposing the underlying strongly folded and faulted pre-Carboniferous basements rocks, and (2) infilling of the incised drainage lines with basalt during the late Tertiary (Rawlings 1967). The latter is responsible for the preservation of Tertiary deposits at Wilmot Dam, located on the Wilmot River just below the junction of the Lea and Isis Rivers (fig. 1).

Here, Tertiary fluvio-lacustrine sediments accumulated in and spilt over from a trough bounded by sets of NNW- and WNW-trending faults within the Ordovician Gordon Limestone and Moina Sandstone basement (fig. 1). Drilling by the Hydro-Electric Commission of Tasmania (HEC) suggests that movement along these faults created a system of lakes in which some 62 m of gravel, sands and clays accumulated during the Tertiary. Lacustrine sedimentation was followed by volcanic activity which buried the area under basaltic breccia and basalt flows (Paterson 1967, Rawlings 1967).

SAMPLES

The samples analysed in this study come from HEC drill hole 4558 drilled in 1965 by the HEC, close to the western margin of the trough where c. 26 m of Tertiary sediments underlie c. 20 m of volcanics (fig. 2).

Two samples of basalt were submitted to K. Henley, Amdel Ltd, South Australia: 43 ft (13.1 m) [TSC58500], a porphyritic olivine basalt with small (1–1.5 mm) phenocrysts of olivine and plagioclase in a holocrystalline groundmass of plagioclase, pyroxene and Fe/Ti oxides; and 63 ft (19.2 m) [TSC58501], a rock similar to the above, except that much of the groundmass consisted of partly

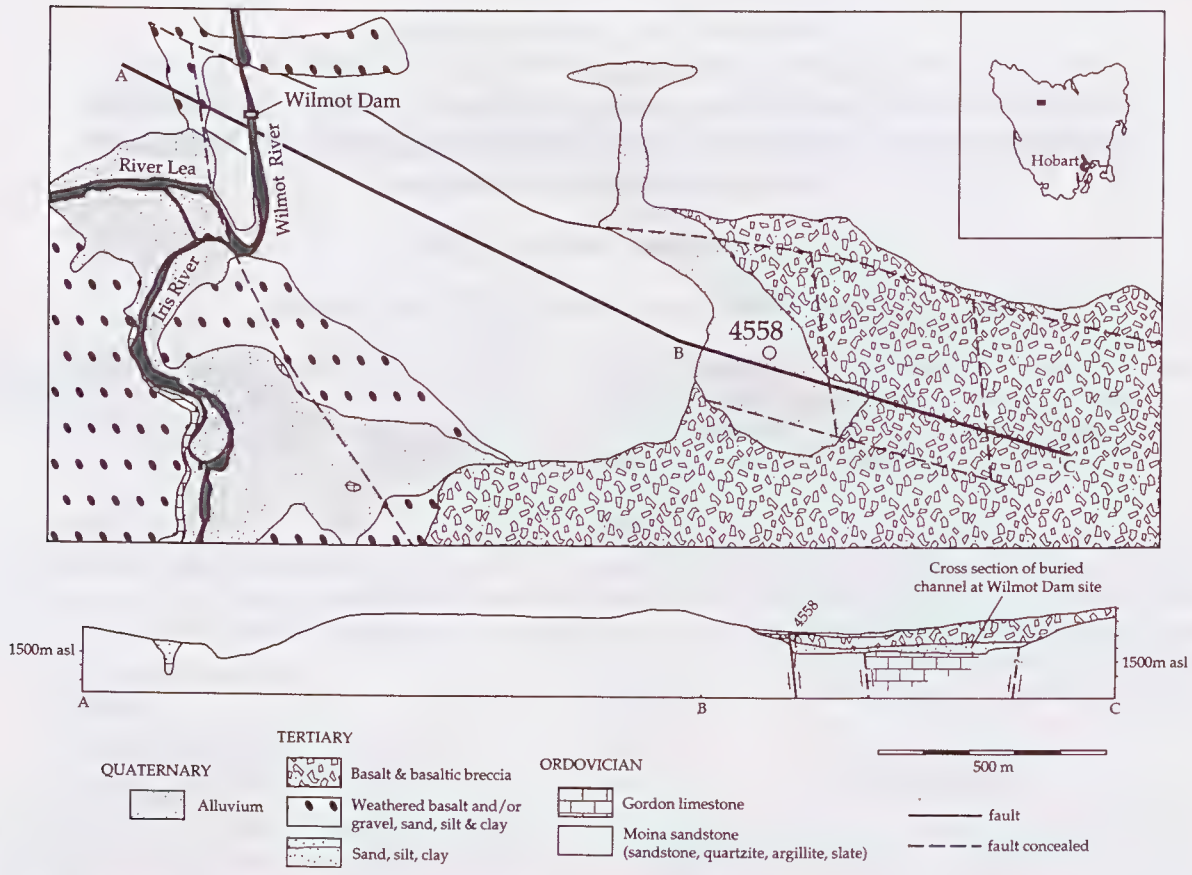

FIG. 1 — Simplified geology of the Wilmot Dam site (after Paterson 1967).

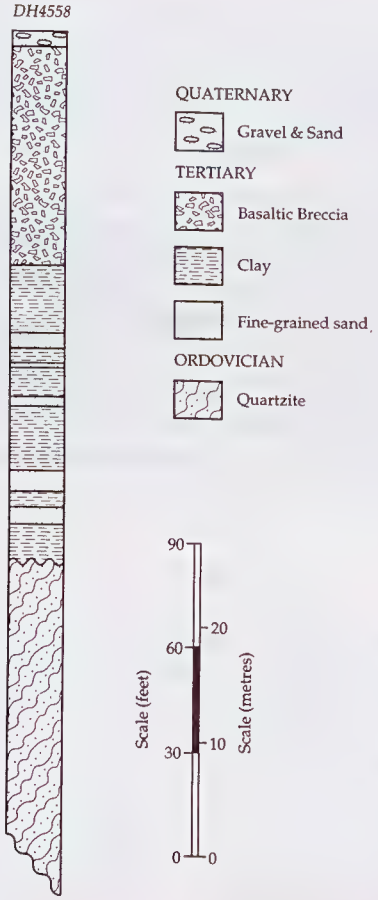

FIG. 2 — Lithostratigraphy of DH 4558 (after Paterson 1967).

devitrified glass. Only the former was considered suitable for K/Ar dating.

Two samples were processed for fossil palynomorphs by K. Weiss, Laola Pty Ltd, Perth: 70 ft (21.3 m), which yielded abundant, well-preserved fossil spores, pollen and cysts of a freshwater dinoflagellate, and 77.5 ft (23.6 m), which yielded moderate numbers of less well-preserved spores and pollen. Age diagnostic and a representative selection of other species are illustrated in plates 1–5: new species are described in appendix 1.

AGE DETERMINATIONS

Potassium/Argon

Apart from patches of a yellow, weakly anisotropic alteration product making up less than 3–5% of the groundmass, the basalt sample at 13.1 m was assessed as fresh and, therefore, able to be dated with an acceptable level of reliability by K/Ar (Amdel Report G6809/93).

Potassium and argon analyses and calculated age are given in table 1. The date of 26.7 Ma approximates to the Middle/Late Oligocene, based on currently accepted boundaries of 35.4 Ma and 23.3 Ma for the Epoch as a whole (Harland *et al.* 1990).

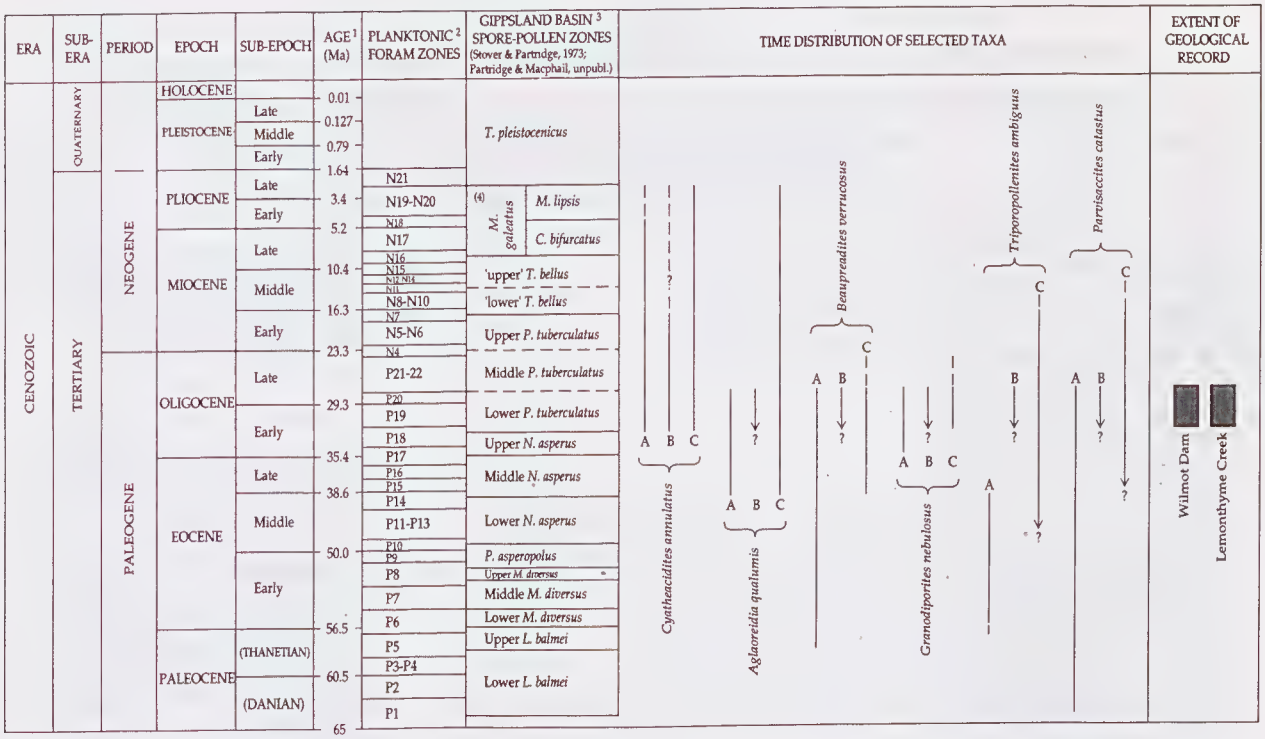

FIG. 3 — Time distribution of age-diagnostic taxa in (A) Gippsland Basin, (B) northwestern Tasmania and (C) Murray Basin, southeastern Australia, shown against the Cenozoic time scale of Harland et al. *(1990). 1, 2 = calibration of Stage boundaries and correlation of planktonic foraminiferal biozones based on Harland* et al. *(1990). 3 = correlation of Gippsland Basin palynological zones against planktonic foraminiferal biozones prepared by A.D. Partridge (8th May 1993). 4 = Murray Basin (Macphail & Truswell, pers. obs.).*

Palynostratigraphy

The stratigraphic distribution of fossil spores and pollen in samples at 21.3 m and 23.6 m is given in table 2. The time distributions of key taxa are shown in figure 3.

Occurrences of *Cyatheacidites annulatus* in both samples provide a reliable lower age limit of Early Oligocene, *Proteacidites tuberculatus* Zone age for sediments near the top of the lacustrine infill (Stover & Partridge 1973). The upper age limit is Lower *P. tuberculatus* Zone, based on multiple occurrences of *Aglaoreidia qualumis, Beaupreaidites verrucosus, Granodiporites nebulosus, Triporopollenites ambiguus* and *Parvisaccites catastus* (pl. 1, A–L).

Species which first appear in the Gippsland Basin within the Early Miocene, Upper *P. tuberculatus* Zone, e.g. *Acaciapollenites myriosporites,* and overlying late Early–Late Miocene, *Triporopollenites bellus* Zone, e.g. *Canthiumidites* (al. *Triporopollenites*) *bellus, Symplocoipollenites austellus* and *Rugulatisporites cowrensis,* are absent.

TABLE 1
K/Ar analyses

Sample	%K	$^{40}Ar^*$ ($\times 10^{-11}$moles/g)	$^{40}Ar^*/^{40}Ar_{total}$	Age†
13.1 m	0.7348	3.4618	0.634	26.7 ± 0.3

* Denotes radiogenic ^{40}Ar.
† Age in Ma with error limits given for the analytical uncertainty at one standard deviation.

DISCUSSION

The lake sediments are older than the dated basalt and, therefore, all or part of the Lower *P. tuberculatus* Zone in northwestern Tasmania is older than 26.7 Ma.

As for other sites in northwestern Tasmania (Hill & Macphail 1983, Macphail *et al.* 1991), the Wilmot Dam palynofloras include a number of species whose time ranges do not overlap in the Gippsland Basin. Examples are: (1) *Chenopodipollis chenopodiaceoides* and (21.3 m) *Foveotriletes lacunosus,* two of the species whose first appearance defines the lower boundary of the Middle *P. tuberculatus* Zone, and (2) *Tricolpites simatus* and (23.6 m) *Triporopollenites ambiguus,* species which range no higher than the Late Eocene, Middle *Nothofagidites asperus* Zone.

TABLE 2
Stratigraphic distribution of fossil spores and pollen at Wilmot Dam and Lemonthyme Creek

Fossil species	Wilmot Dam DDH 4558	Lemonthyme DDH 5825		Modern analogue
	21.3 m	23.6 m	20.1–45.3 m	
(a) Algae				
Pseudoschizea circula	-	+	+	indet. soil? algae
Saeptodinium sp.	1	-	3	Freshwater dinoflagellate
(b) Fungi				
Pesavis cf. *tagluensis*	-	+	+	indet. fungus
Unidentified sporae dispersae	-	-	+	indet. fungus
(c) Ferns & Fern Allies				
Baculatisporites disconformis	+	+	2	Liverworts
Bryosporis anisopolaris	-	-	+	Mosses
Cyatheacidites annulatus	+	+	+	*Lophosoria quadrapinnata*
Cyathidites australis	+	+	1	ground ferns
Cyathidites paleospora	+	+	-	Cyatheaceae
Cyathidites splendens	+	-	+	*Acrostichum*?
Dictyophyllidites arcuatus	+	-	-	Gleicheniaceae
Foveotriletes balteus	+	+	+	Lycopodiaceae
Foveotriletes lacunosus	+	-	-	*Lycopodium varium*-type
Foveotriletes palaequetrus	+	-	+	*Lycopodium australium*-type
Gleicheniidites spp.	+	-	+	Gleicheniaceae
Herkosporites elliotii	+	-		*Lycopodium deuterodensum*-type
Ischyosporites-Triletes complex	10	15	+	indet. lycopsids
Laevigatosporites spp.	2	2	1	Blechnaceae?
Latrobosporites crassus	+	-	+	indet. lycopsid
Latrobosporites marginis	+	+	+	*Lycopodium laterale*-type
Matonisporites ornamentalis	+	+	1	Dicksoniaceae
Osmundacites sp.	-	+	-	Osmundaceae?
Peromonolites densus	-	-	+	Blechnaceae?
P. vellosus	+	-	-	Blechnaceae?
Polypodiisporites histiopteroides	-	+	-	*Histiopteris*
Reticuloidaesporites spp.	+	3	+	indet. fern
Retitriletes australoclavatidites	+	+	+	Lycopodiaceae
Rugulatisporites mallatus	-	-	+	*Culcita dubia*-type
Stereisporites australis	+	+	1	*Sphagnum*
Verrucosisporites cristatus	+	+	+	indet. lycopsid?
Verrucosisporites kopukuensis	+	+	+	indet. lycopsid?
(d) Gymnosperms				
Araucariacites australis	2	5	1	Araucariaceae
Cupressaceae-Taxodiaceae	6	3	1	Cupressaceae-Taxodiaceae
Dacrycarpites australiensis	+	3	2	*Dacrycarpus*
Diluynites granulatus	+	+	+	Araucariaceae
Lygistepollenites florinii	2	+	1	*Dacrydium* Group B spp.
Microalatidites paleogenicus	1	+	+	*Phyllocladus*
Microcachrydites antarcticus	+	+	1	*Microcachrys*
Parvisaccites catastus	+	+	-	*Dacrydium bidwillii*-type
Phyllocladidites mawsonii	8	10	17	*Lagarostrobos franklinii*
Podocarpidites spp.	6	12	12	*Podocarpus/Dacrydium*
Podosporites erugatus	+	-	+	*Microstrobos*
P. parvus	2	1	3	*Microcachrys*?
P. microsaccatus	-	+	-	indet. Podocarpaceae
Trichotomosulcites subgranulosus	-	+	-	indet. Podocarpaceae
(e) Angiosperms				
Aglaoreidia qualumis	+	+	-	Sparganiaceae/Typhaceae
Banksieaeidites elongatus	-	+	-	*Banksia*
Beaupreaidites elegansiformis	+	+	+	*Beauprea*
B. verrucosus	+	+	+	*Beauprea*
Chenopodipollis chenopodiaceoides	+	+	+	Chenopodiaceae
Clavatipollenites glarius	-	-	+	*Ascarina*
Cupanieidites orthoteichus	+	-	+	Sapindaceae (Cupanieae)
Cyperaceaepollis neogenicus	+	+	-	Cyperaceae
Dodonaea triquetra-type	+	+	-	*Dodonaea triquetra*
Droseraceae	+	-	+	Droseraceae
Dryadopollenites retequetrus	+	-	-	indet. angiosperm
Ericipites crassiexinus	-	+	-	Ericales
E. scabratus	+	3	+	Ericales
Gothanipollis cf. *bassensis*	+	+	+	Loranthaceae
G. cf. *gothanii*	+	+	+	Loranthaceae

cont.

Fossil species	Wilmot Dam DDH 4558	Lemonthyme DDH 5825		Modern analogue
	21.3 m	23.6 m	20.1–45.3 m	
G. perplexus	-	-	+	Loranthaceae
Granodiporites nebulosus	+	+	+	*Embothrium*
Gyropollis psilatus	-	-	+	Gyrostemonaceae
Haloragacidites harrisii-Casuarinidites cainozoicus	1	4	3	Casuarinaceae
Ilexpollenites anguloclavatus	-	+	+	*Ilex*
Liliacidites lanceolatus	+	+	+	Liliaceae
Malvacipollis spinyspora	+	+	+	*Micrantheum*
M. subtilis	+	+	+	*Austrobuxus*
Margocolporites cf. *scaboratus*	+	-	-	indet. angiosperm
Milfordia homeopunctatus	+	-	-	Restionaceae
M. hypolaenioides	+	+	-	Restionaceae
Mutisiapollis patersonii	+	+	+	*Mutisia*
Myrtaceidites parvus-mesonesus	1	+	+	Myrtaceae (not *Eucalyptus*)
Nothofagidites asperus	1	+	3	*Nothofagus* (*Lophozonia*)
N. brachyspinulosus	5	5	4	*Nothofagus* (*Fuscospora*)
N. deminutus-vansteenisii	+	+	2	*Nothofagus* (*Brasssopora*)
N. emarcidus-heterus	37	24	29	*Nothofagus* (*Brassospora*)
N. falcatus	+	+	+	*Nothofagus* (*Brassospora*)
N. flemingii	2	1	6	*Nothofagus* (*Nothofagus*)
N. goniatus	-	-	+	*Nothofagus* (*Lophozonia*?)
Palaeocoprosmadites zelandiae	-	+	-	*Coprosma*/*Opercularia*
pentacolporate sp.	+	+	-	Meliaceae?
Periporopollenites demarcatus	+	-	+	Trimeniaceae?
P. hexaporus	+	+	+	Trimeniaceae?
P. vesicus	1	+	+	Trimeniaceae?
Polyorificites oblatus	+	-	+	indet. angiosperm
Proteacidites adenanthoides	-	-	+	*Adenanthos*?
P. annularis	-	-	+	*Xylomelum*
P. obscurus	+	+	+	*Agastachys*-type
P. latrobensis	+	-	+	indet. Proteaceae
P. pseudomoides	+	-	+	indet. Proteaceae
P. reticuloscabratus	-	-	+	*Gevuina*/*Hicksbeachia*
P. scaboratus	+	+	+	*Macadamia*-type
Proteacidites spp.	3	4	3	Proteaceae
Pseudowinterapollis cranwellae	+	-	+	*Tasmannia*
Quintiniapollis psilatispora	+	-	+	*Quintinia*
Retistephanocolpites sp. aff. *Callitriche*	-	+	-	Callitrichaceae
Rhoipites sp. cf. *Muehlenbeckia*	+	+	-	*Muehlenbeckia*
Sapotaceoidaepollenites latizonatus	+	+	+	Sapotaceae
S. rotundus	-	-	+	Sapotaceae
Sparganiaceaepollenites sphericus	+	+	-	Sparganiaceae
Stephanocolpites oblatus	+	+	-	*Haloragodendron*
S. sphericus	-	-	+	indet.
Striasyncolpites laxus	-	-	+	Menyanthaceae
Tetracolporites palynius	+	+	-	*Ixerba*?
Tricolpites reticulatus	+	-	+	*Gunnera*
T. simatus	+	+	+	Loranthaceae
T. stylidioides	+	+	+	Stylidiaceae
T. trioblatus	+	+	+	Scrophulariaceae
Tricolpites spp.	+	+	+	indet. angiosperms
Tricolporites cf. *adelaidensis*	+	+	+	indet. angiosperm
Tricolporites leuros	-	-	+	indet. angiosperm
T. microreticulatus	+	+	-	indet. angiosperm
T. paenestriatus	+	-	-	indet. angiosperm
Tricolporites spp.	3	+	3	indet. angiosperms
Tetrapollis campbellbrownii	+	-	-	Haloragaceae?
Triporopollenites ambiguus	-	+	+	*Telopea* — type
T. sp. cf. *T. chnosus*	+	+	+	indet. Proteaceae
Pollen sum	492	355	393	

Relative abundance values expressed as a percentage of the total identifiable pollen and spore count (excluding algae, fungi and liverworts). Percentages less than 1% are given as +.

This almost certainly reflects differences in topography, local climate and depositional environment between the deeply incised, moderate to high plateaux, characteristic of northwestern Tasmania, and the Gippsland Basin, which was a low-lying coastal plain, backed by extensive freshwater peat swamps in the Latrobe Valley Depression (Sluiter & Kershaw 1982, Holdgate & Sluiter 1991) and, as now, open to the Tasman Sea to the southeast.

Nevertheless, the palynological age determination of Lower *P. tuberculatus* Zone is in excellent agreement with both the K/Ar date of 26.7 Ma and Stover & Partridge's conclusion (1973: 243–244) that the top of the Middle *P. tuberculatus* Zone approximates to the Oligocene–Miocene boundary. We conclude, therefore, that the criteria proposed by Stover & Partridge (1973) are a reliable method for dating strata of Oligocene, *P. tuberculatus* Zone age in Tasmania. Some uncertainty still exists regarding strata of Early Miocene, *P. tuberculatus* Zone age, since the earliest record to date of any index species of the overlying *T. bellus* Zone is Late Pliocene — *Symplocoipollenites austellus* at Linda Valley, western Tasmania (Macphail *et al.*, in prep.).

The Wilmot Dam palynofloras are virtually identical in composition to fossil assemblages recovered from a 34 m thick sequence of laminated clays and silts overlying a tillite at Lemonthyme Creek in the adjoining Forth Valley (Paterson *et al.* 1967). Age-diagnostic species common to both deposits include *Cyatheacidites annulatus, Beaupreaidites verrucosus, Granodiporites nebulosus, Parvisaccites catastus* and *Triporopollenites ambiguus* (table 2).

Reinforcing the impression that the deposits are coeval are occurrences of two new species (appendix 1) that appear to be restricted to *P. tuberculatus* Zone palynofloras in Tasmania: *Periporopollenites hexaporus* and *Mutisiapollis patersonii.* Other distinctive shared taxa include Droseraceae and *Tricolpites stylidioides* (pls 1, 2).

Basalts associated with the Lemonthyme deposit are unsuitable for K/Ar dating and, based on spore-pollen evidence alone, Macphail *et al.* (1993a) concluded that the tillite was most probably Early Oligocene and highly unlikely to be younger than Late Oligocene. This makes the (local) glaciation responsible for deposition of the tillite the oldest recorded to date, outside of Antarctica during the Cenozoic. The Early–Middle Oligocene date for the Wilmot Dam palynosequence supports and strengthens this conclusion.

The latest Eocene–earliest Oligocene is widely seen as a critical period in the history of Cenozoic global cooling, and a significant number of tree and shrub taxa that had been typical of Eocene megatherm–mesotherm rainforest in the Bass Strait region did not survive into Oligocene time (Macphail *et al.* 1994). Nevertheless, it is equally clear from sites such as Wilmot Dam and Lemonthyme Creek that the Tasmanian flora continued to be enriched by new species, either through continued differentiation of the original Gondwanic stock in Australia or through long-distance dispersal, probably via Antarctica.

It is tempting to speculate that the former (autochthonous) group includes *Periporopollenites hexaporus,* possibly derived from the same Trimeniaceaen stock as *P. demarcatus,* which first apppears in southeastern Australia during the Maastrichtian. The first appearance of *Mutisiapollis patersonii* and *Tricolpites stylidioides* are more likely to be due to long-distance dispersal via Antarctica for two reasons. Firstly, both taxa include modern representatives in South America (Mabberley 1989). Secondly, palaeogeographic evidence (Veevers *et al.* 1991) shows that, during the Early Oligocene, Tasmania was a mountainous peninsula at about latitude 55°–63°, separated from Antarctica by the circum-Antarctic Ocean. Both appear to be the oldest fossil records to date of these taxa (compare Muller 1981).

ACKNOWLEDGEMENTS

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PLATE 1

Age-diagnostic taxa. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm.
Cyatheacidites annulatus *Cookson, 1947, × 788. (A) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (B) Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (C) Lemonthyme DH 5825 at 30.8 m,* P. tuberculatus *Zone; (D) Lemonthyme DH 5825 at 24.7 m,* P. tuberculatus *Zone.*
Parvisaccites catastus *Stover & Partridge, 1973. (E) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone.*
Granodiporites nebulosus *Stover & Partridge, 1973. (F) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (G) as above, phase contrast showing scattered granulae.*
Triporopollenites ambiguus *Stover & Partridge, 1973. (H) Lemonthyme DH 5825 at 45.3 m,* P. tuberculatus *Zone.*
Beaupreaidites verrucosus *Cookson, 1950. (I) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (J) Lemonthyme DH 5825 at 30.1 m,* P. tuberculatus *Zone phase contrast; (K) Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone phase contrast.*
Aglaoreidia qualumis *Stover & Partridge, 1973. (L) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone.*
Tetrapollis campbellbrownii *Macphail & Truswell, 1993. (M) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (N) as above, phase contrast showing grooved nexine around pores.*
Pesavis *sp. cf.* P. tagluensis *(Elsik & Jansonius, 1974); × 788; (O) Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; unidentified Fungi Sporae Dispersae; × 788; (P) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

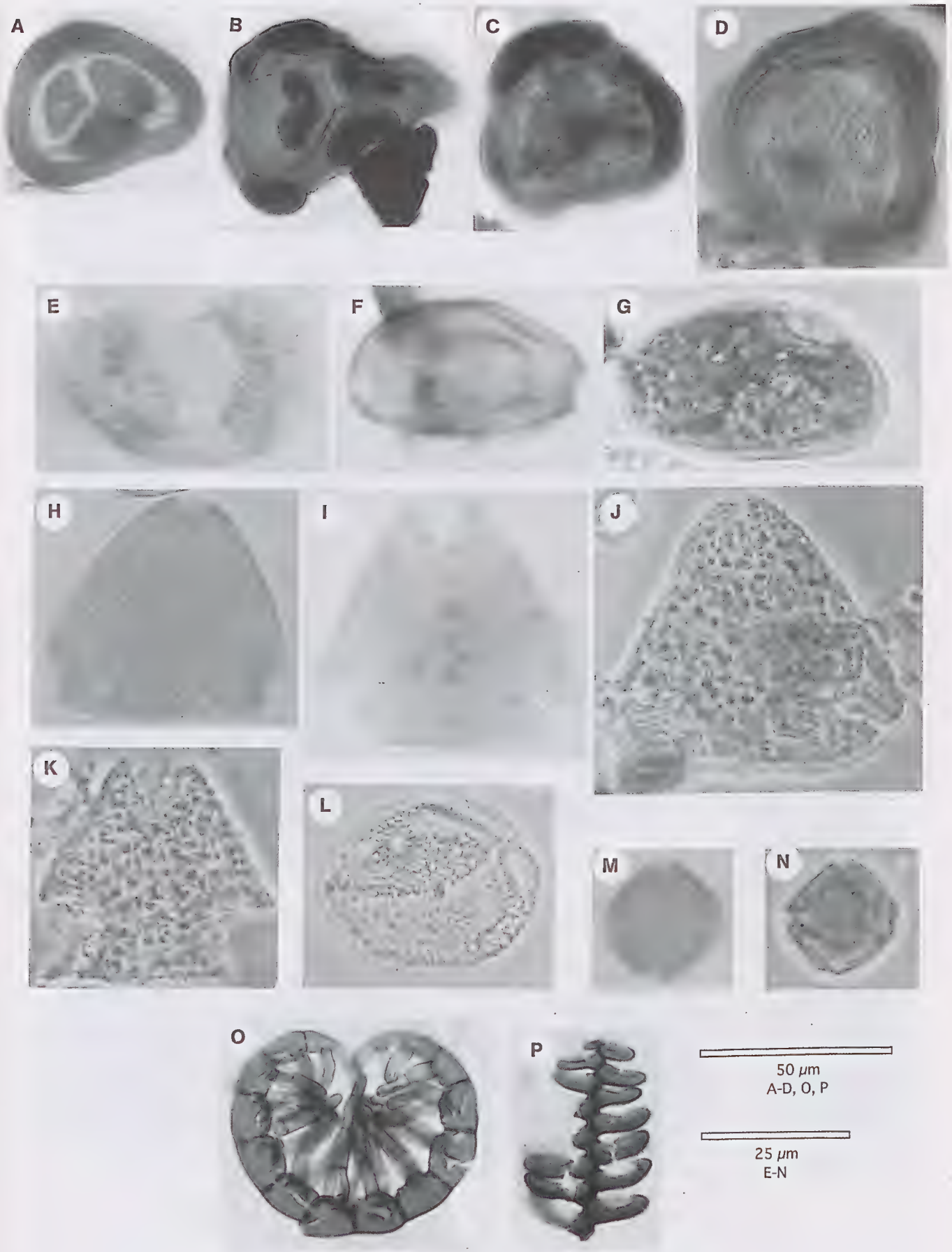

PLATE 1

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(accepted 1 June 1993)

PLATE 2

New species. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm.

Tricolpites stylidioides *n. sp. (A–D) Holotype at three focal planes; equatorial view; figure 4 phase contrast — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (E) paratype; polar view of unusually small specimen — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (F) paratype; equatorial view — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (G) specimen showing mesocolpial thickening of nexine — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (H) specimen showing irregular margins of colpi — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (I) specimen showing strongly thickened nexine at poles — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (J) unusually large oblate specimen (crushed) — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone.*

Mutisiapollis patersonii *n. sp. (K–N) Holotype at three focal planes; equatorial view; figure 14 phase contrast — Lemonthyme DH 5825 at 30.8 m,* P. tuberculatus *Zone; (O–P) oblique polar view; figure 14 phase contrast showing puncto-reticulate tectum — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (Q–R) equatorial view at two focal planes of a grain showing an undulating, micro-echinate tectum in which the puncta have joined to form fossulae; (S) equatorial view of small specimen with unusually well-developed micro-echinate sculpture — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (T) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (U) Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone.*

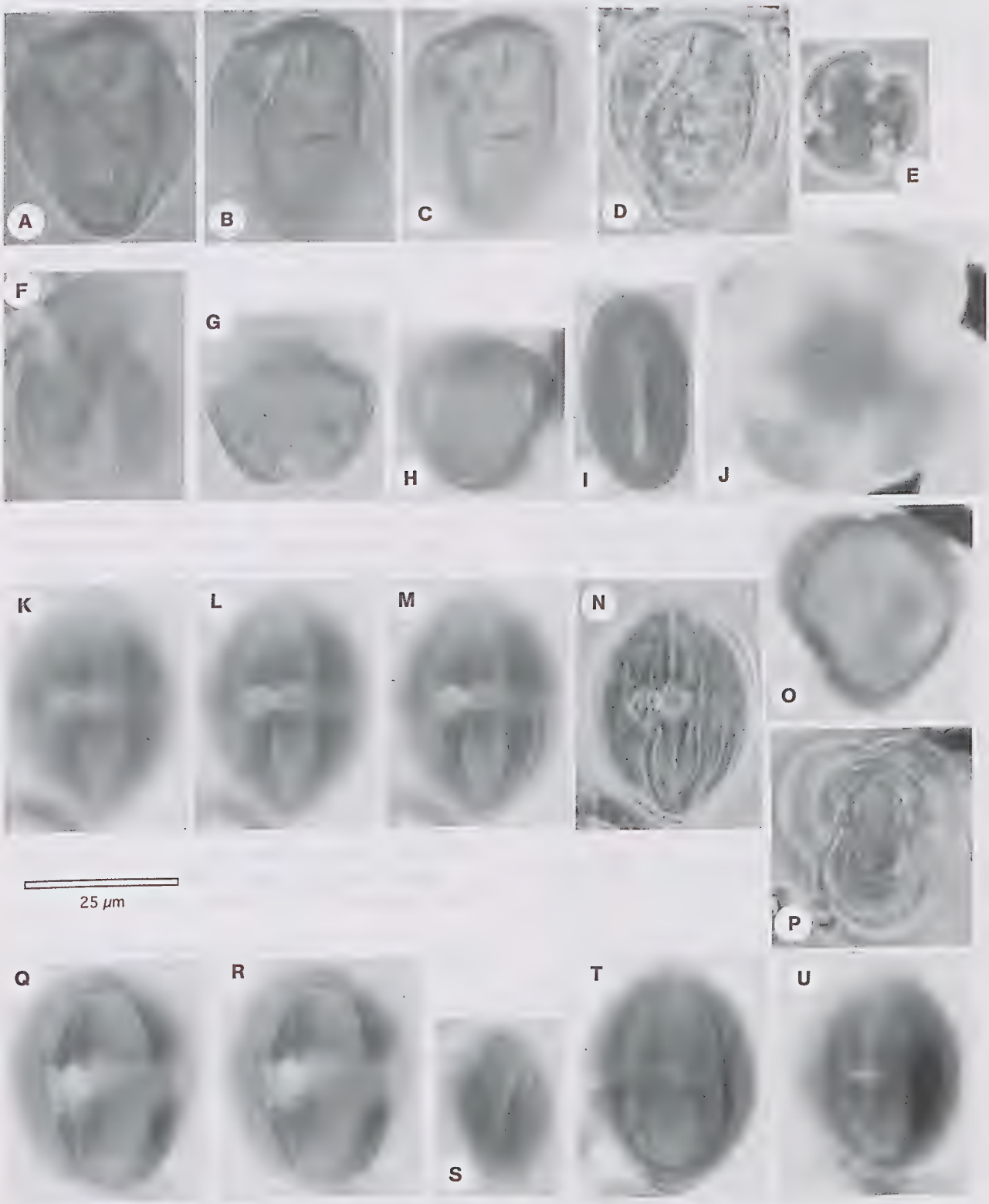

PLATE 2

APPENDIX 1

Although the Wilmot Dam and Lemonthyme Creek palynofloras are dominated by long-ranging taxa, chiefly *Nothofagus* and Podocarpaceae, they include a number of rare to uncommon types that, to date, have only been recorded in Tasmania, e.g. *Mutisiapollis patersonii* n.sp. and *Periporopollenites hexaporus* n.sp. Others are the oldest records anywhere, e.g. *Tricolpites stylidioides* n. sp., or significantly extend the known geographic range of the taxon, e.g. *Tetrapollis campbellbrownii* Macphail & Truswell, 1993.

NEW SPECIES

Tricolpate Pollen

GENUS *Tricolpites* Cookson, 1947 ex Couper, 1953

TYPE SPECIES *Tricolpites reticulatus* Cookson, 1947 (subsequent designation by Couper, 1953)

Tricolpites stylidioides n.sp. (pl. 2, A–J)

HOLOTYPE. Slide SB W-001, stored in the Department of Plant Science, University of Tasmania. England Finder co-ordinates R43(2). Paratypes at O40(4), R45(1), T37(0), T43(2), U41(0) and W67(0) on the same slide.

TYPE LOCALITY. HEC drillhole 5825, Lemonthyme Creek (41°37'S,146°09'E), at 136.0 ft (41.45 m), Early Oligocene.

DERIVATION OF NAME. From the presumed botanical affinity with the Stylidiaceae.

DIAGNOSIS. Monad, isopolar, radiosymmetric, stephanocolpate, apertures three, less frequently four, elongate, usually gaping with ragged margins, subprolate–suboblate, usually distorted (compressed oval), crushed grains oblate; amb subcircular; exine 1–1.5 µm at equator increasing to 3 µm at pole, nexine markedly thicker than sexine, thickening across poles, intectate, apiculate, apiculae short and narrow, < 0.5 µm high, scattered at regular intervals c. 1 µm apart.

DIMENSIONS. Polar diameter 25–(28)–40 µm, eight specimens measured; equatorial diameter 20–(31)–45 µm, ten specimens measured.

BOTANICAL AFFINITY. *Forstera/Phyllachne* (Stylidiaceae).

KNOWN DISTRIBUTION. Tasmania — Early Oligocene to present; Gippsland Basin — earliest Oligocene to terminal Pliocene; central–west Murray Basin — Oligocene to Late Miocene.

DISCUSSION. The type closely resembles pollen of the Stylidiaceae, in particular *Fostera* Linn. f., a very small genus of perennial herbs now confined to montane–subalpine habitats in Tasmania, New Zealand and Fuegia. Tetracolpate, suboblate specimens approximate to the type produced by *Phyllachne* J.R. et G. Forst. The only widespread lowland member of the family in Australia, *Stylidium graminifolium* Swartz, produces strongly oblate pollen with five to six gaping colpi with rounded apices, a type not recorded earlier than Late Pliocene sediments in Tasmania.

Specimens from northwestern Tasmania are the oldest fossil pollen record of the family to date. The presence of *Tricolpites stylidioides* in laminated claystones and siltstones within and overlying the tillite at Lemonthyme Creek (Macphail *et al.* 1993) firmly links the establishment of the family in Tasmania with Cenozoic global cooling.

Tricolporate Pollen

GENUS *Mutisiapollis* n.gen.

TYPE SPECIES *Mutisiapollis patersonii* n.sp.

DERIVATION OF NAME. From the presumed botanical affinity with *Mutisia* L.f. (Asteraceae tribe Mutisieae).

DIAGNOSIS. Monad, isopolar, radiosymmetric; tricolporate, colpi long, endocolpi lalongate; subprolate–prolate, amb subcircular; exine >4 µm thick at equator, sexine clearly stratified with a basal layer of thick columellae separated by an internal tectal layer from an outer layer of short, fine columellae, tectum undulate, puncto-reticulate, microechinate.

DISCUSSION. *Mutisia* is a moderate-sized genus of shrubs and lianes, more or less confined to the Andes in South America. Its pollen is said to be distinct from that produced by other genera within the tribe Mutisieae (Stix 1960) although transmission electron microscopy (Skvarla *et al.* 1977) has established that the pollen type falls within the Anthemoid pattern, also found within the tribes Anthemideae and Cynareae.

We are unaware whether fossil *Mutisia*-type pollen has been described from pre-Quaternary sediments in South America but note that Partridge (1978) referred a species of *Tubulifloridites* with well-developed echini, recovered from Late Tertiary sediments at DSDP Site 365 off the west coast of Africa, to *Mutisia* or *Echinops* (Cynareae) .

Mutisiapollis patersonii n.sp., *non* Partridge, 1978, Fig. 12 (pl. 2, K–U)

DERIVATION OF NAME. After S.J. Paterson who, as Chief Geologist with the HEC, was responsible for the identification of Tertiary sediments at the Wilmot Dam site.

HOLOTYPE. Slide SB W–002, housed in the Department of Plant Science, University of Tasmania, England Finder co-ordinates S43(4); paratype at M29(2) on the same slide.

TYPE LOCALITY. HEC drillhole 5825, Lemonthyme Creek (41°37'S, 146°09'E), at 101 ft (30.8 m), early Oligocene.

DIAGNOSIS. Monad, isopolar, radiosymmetric; tricolporate, colpi extending to near poles, endocolpi lalongate c. 5 × 7 µm, oval to diamond-shaped, lateral margins often indistinct or ragged; exine 4–7 µm thick at equator decreasing to 2.5–4 µm at poles, nexine thinner than sexine but swelling to c. 3 µm around endocolpi, sexine consisting of a basal layer of thick simplibaculate columellae 1.5–3 µm long, separated by a homogeneous layer from an outer layer of fine columellae <0.8 µm, surface of tectum often undulate in sectional view, appearing scabrate–verrucate in surface view due to subtectum structure, puncto-reticulate, microechinate.

DIMENSIONS. Polar diameter 20–(36)–40 µm, nine specimens measured; equatorial diameter 20–(27)–32 µm, eight specimens measured.

DISTRIBUTION Northwestern Tasmania: Early to Middle? Oligocene; not recorded elsewhere to date.

DISCUSSION Apart from variations in size, there is little to distinguish *Mutisiapollis patersonii* from pollen of *Mutisia speciosa* (fig. 62A in Erdtman 1966), *M. decurrens* and *M. spectabilis* (Heusser 1971: 30-31, pl. 23, figs 273, 274). *Echinops* is rambibaculate and lacks the secondary columellate layer in the subtectum (Erdtman 1966, fig. 64). *Polupissusites* Salard-Cheboldaeff emend. Pocknall, 1982 is rambibaculate and characterised by exine which thickens across the poles.

The records of *Mutisiapollis patersonii* are amongst the earliest for any member of the Asteraceae anywhere (see Muller 1981). Its Cenozoic distribution in Tasmania is similar to *Cyatheacidites annulatus,* in that both first appear during the Early Oligocene whilst the modern sources are now confined to South America. A logical explanation is that Antarctica was the centre of origin/ dispersal for both taxa.

Periporate Pollen

GENUS *Periporopollenites* Pflug & Thomson, 1953

TYPE SPECIES *Periporopollenites stigmosus* Potonie, designated by Pflug & Thompson in Thompson & Pflug 1953

Periporopollenites hexaporus n.sp. (pl. 3, A–J)

1991 Unknown species Macphail *et al.*: 96, fig. 5M–O

HOLOTYPE Slide SB W–003, stored in the Department of Plant Science, University of Tasmania: England Finder co-ordinates R47(3); paratype at X46(0) on the same slide.

TYPE LOCALITY HEC drillhole 5825, Lemonthyme Creek (41°37'S, 146°09'E), at 102 ft (31.1 m), Early Oligocene.

DERIVATION OF NAME From the characteristic number of pores.

DIAGNOSIS Monad, apolar, sphaeroidal although often compressed into a cubical to polyhedrol shape; periporate, pores six, rarely 12, large, circular, 4–7 µm, weakly annulate; exine 1.5–2.5 µm thick, sexine twice as thick as nexine, columellae coarse, clavate–gemmate, heads wholly or partially fused to form a thin tectum, puncto-reticulate.

DIMENSION 22–(25)–32 µm, 13 specimens measured.

BOTANICAL AFFINITY Trimeniaceae?

DISTRIBUTION Northwestern Tasmania: Early Oligocene to Late Oligocene/Early Miocene; not recorded elsewhere to date.

DISCUSSION. Stover & Partridge (1973: 272) have used Periporopo*llenites* to accommodate fossil periporate pollen characterised by ten to approximately 32 simple apertures and exine that is clearly stratified and thin, relative to the size of the grain. In spite of the lower number of pores, relatively thick exine and verrucate sculpture, *P. hexaporus* appears to be related to *P. demarcatus* Stover & Partridge, 1973 via intermediate forms (see below). For this reason we prefer to retain the species within *Periporopollenites* rather than accommodate the type in *Parsonsidites* Couper, 1960 (erected to cover psilate to scabrate grains with five or more pores) or *Polyporites* Samoilovich & Mtchedlishvili, 1961(erected to cover grains with five to six pores and pilate exine).

Most populations of *Periporopollenites hexaporus* include specimens characterised by thin pilate columellate, semi-tectate exine (often corroded) and with 10 to 18 (av. 12) pores which may or may not be surrounded by annuli (pl. 3, K–M). Further work is required to assess whether this morphotype warrants species status. At present, we prefer to regard it as an intermediate between hexa*porus* and the *demarcatus-vesicus* complex (pl. 3, N–Q) and suggest that all species are part of the same (Trimeniaceaen?) phylogenetic lineage. If correct, the (to date) restriction of P. he*xaporus* to Tasmania is evidence of local evolution within this family.

OTHER TAXA

Trilete Spores

Cyatheacidites annulatus Cookson, 1947 (pl.1, A–D)

Spores with this morphology are now only found within the monospecific South American tree-fern family Lophosoriaceae.

The fossil taxon has a markedly disjunct time distribution in Australia: *Cyatheacidites tectifera* which first appears in the late Albian and becomes extinct in the Campanian, and *C. annulatus* which first appears in the early Oligocene and becomes extinct during the Pliocene. This almost certainly reflects two separate, ultimately unsuccessful colonisation events. Based on the variations in the morphology of the three raised pads on the proximal surface, several subspecies may have evolved within the C. *annulatus* lineage during the late Tertiary.

Tricolpate Pollen

Gothanipollis perplexus Pocknall & Mildenhall, 1984 (pl. 5, A)
Gothanipollis sp. cf *G. gothanii* Krutzsch, 1959 (pl. 4, B)
Gothanipollis sp. cf *G. bassensis* Stover & Partridge, 1973 (pl. 5, C)
Tricolpites simatus Stover & Partridge, 1973 (pl. 5, D)

Although now extinct in Tasmania, Gotha*nipollis* spp. and *Tricolpites simatus* show that Loranthaceae were part of the regional flora from the late Early Eocene into the Middle Pleistocene (Macphail *et al.* 1993c). Interestingly, the first appearance of Loranthaceae pollen in Tasmania is earlier and extinction of the type later than in the Gippsland Basin (compare Stover & Partridge 1973).

Tricolporate Pollen

Margocolporites sp. cf *Anopterus* (pl. 4, H–I)

This psilate tricolporate type broadly resembles modern *Anopterus* (Escalloniaceae) pollen in having strongly developed margo costae and pronounced endo-cracking of the exine.

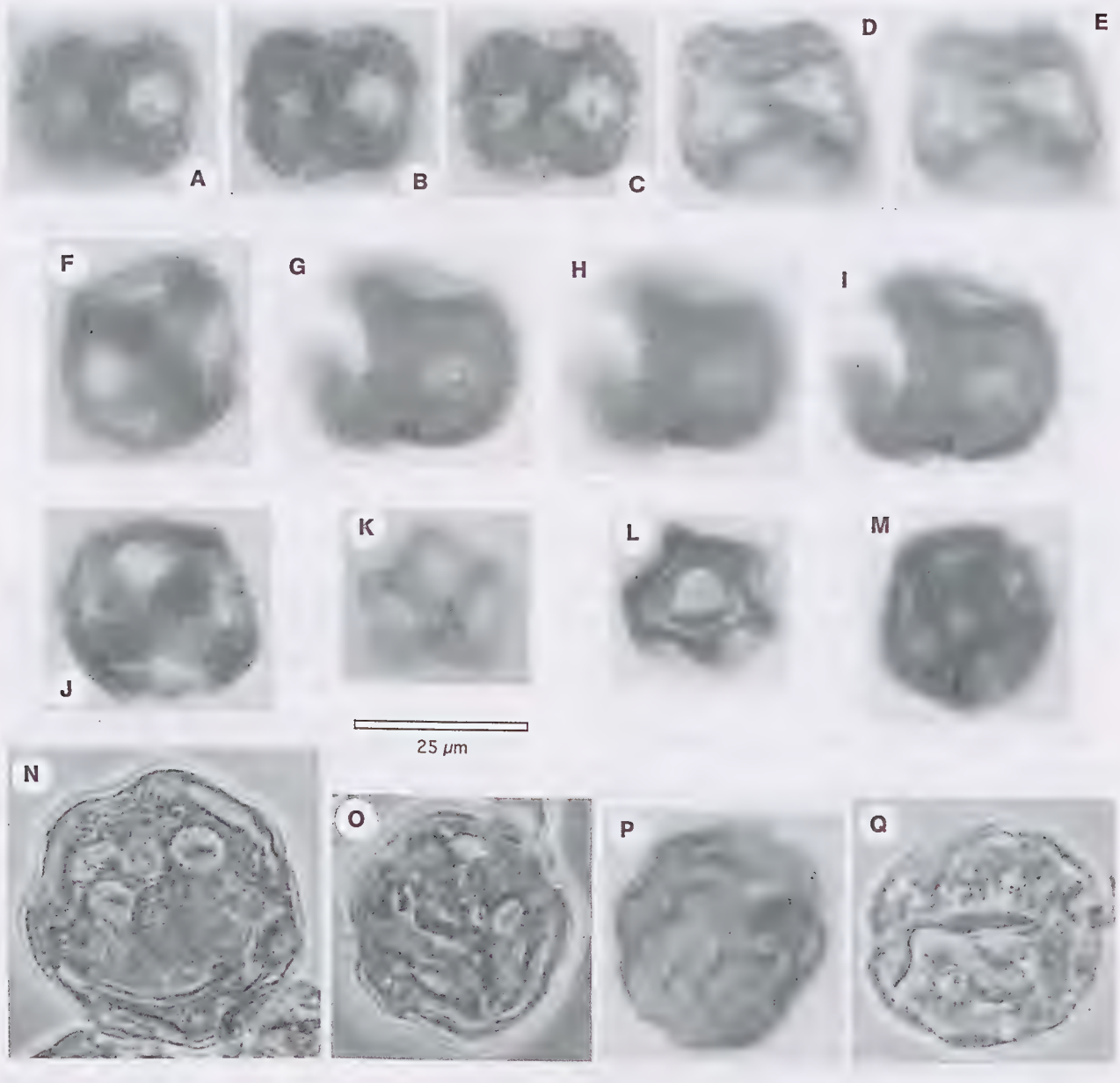

PLATE 3

New species (continued). All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm.
Periporopollenites hexaporus *n. sp. (A–C) Holotype at three focal planes; oblique view — Lemonthyme DH 5802 at 31.1 m,* P. tuberculatus *Zone; (D–E) paratype at two focal planes; oblique view — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (F) specimen showing strongly developed verrucate ornamentation — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (G–I) specimen showing (1) poroid split in nexinous membrane across pore and (2) fusion of clavate columellae to form a verrucate tectum — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (J) specimen showing clavate columellae more or less reduced to gemmae; semi-tectate — Lemonthyme DH 5802 at 46 µ,* P. tuberculatus *Zone; (K) specimen intermediate between* P. hexaporus *and* P. demarcatus; *12 pores present; columellae pilate; tectum thin, corroded; annuli absent around pores — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (L) 10-porate grain with well developed annuli — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (M) 18-porate specimen with well-developed annuli — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone.*
Periporopollenites demarcatus *Stover & Partridge, 1973. (N) Crushed, unusually large specimen; note puncto-reticulate tectum; phase contrast — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (O) as above; phase contrast — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone.*
Periporopollenites vesicus *Stover & Partridge, 1973. (P) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone.*
Periporopollenites *sp. cf.* P. polyoratus *(Couper) Stover & Partridge, 1973. (Q) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

Tetraporate Pollen

Tetrapollis campbellbrownii Macphail & Truswell 1993 (pl. 1, H–I)

This species, first described from Oligocene–late Early Miocene sediments in the Murray Basin, is characterised by four (rarely three or five) pores surrounded by channeled nexine: columellae are not visible but the sexine is clearly stratified into two layers, the outermost of which tends to be undulate.

Although difficult to photograph, all features are displayed by the Wilmot Dam specimen. The species is widespread in Oligo–

PLATE 4 (see next page)

Woody taxa. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm. (A) Microcachrydites antarcticus *Cookson, 1947 — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (B)* Podosporites erugatus *Mildenhall, 1978 — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (C)* Nothofagidites flemingii *(Couper) Potonié, 1960 — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (D)* Quintiniapollis psilatispora *(Martin) Mildenhall & Pocknall, 1989 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (E)* Sapotaceoidaepollenites latizonatus *(McIntyre) Pocknall & Mildenhall, 1984 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (F–G) pentacolporate sp. Meliaceae[?]; this type differs from five-pored specimens of* Tetracolporites palynius *Stover & Partridge, 1982, in that the nexine is strongly thickened around the pores; polar view — (F) equatorial view; (G) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (H)* Margocolporites *sp. cf.* Anopterus *(Escalloniaceae). Polar view; note prominent margo colpae and pronounced endocracks in exine — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (I) as above; phase contrast — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (J) as above; equatorial view; it is uncertain whether the crossed longitudinal colpi are characteristic of the type — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (K)* tetraporate *sp. cf* Tricolporites adelaidensis *Stover & Partridge, 1982; the specimen falls within the size and pore range but it lacks the gaping, short colpi characterising this species;* Tetracolporites spectabilis *Pocknall & Mildenhall is brevicolpate with annulate ora — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (L–M)* Tricolporites *sp. cf.* Muehlenbeckia *(Polygonaceae); the species is characterized by the finely scabrate sculpture and diamond-shaped lalaongate endocolpi — Wilmot Dam DH 4588 at 23.6 m,* P. tuberculatus *Zone; (N)* Rhoipites (al. Tricolporites) microreticulatus *Harris, 1965 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (O)* Dryadopollis retequetrus *(Stover & Partridge), Pocknall & Mildenhall, 1984; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (P) cf.* Dryadopollis retequetrus *(Stover & Partridge), Pocknall & Mildenhall, 1984; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (Q)* Beaupreaidites elegansiformis *Cookson, 1950; phase contrast — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (R)* Triporopollenites *sp. cf.* T. chnosus *Stover & Partridge, 1973; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (S)* Malvacipollis subtilis*; phase contrast — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

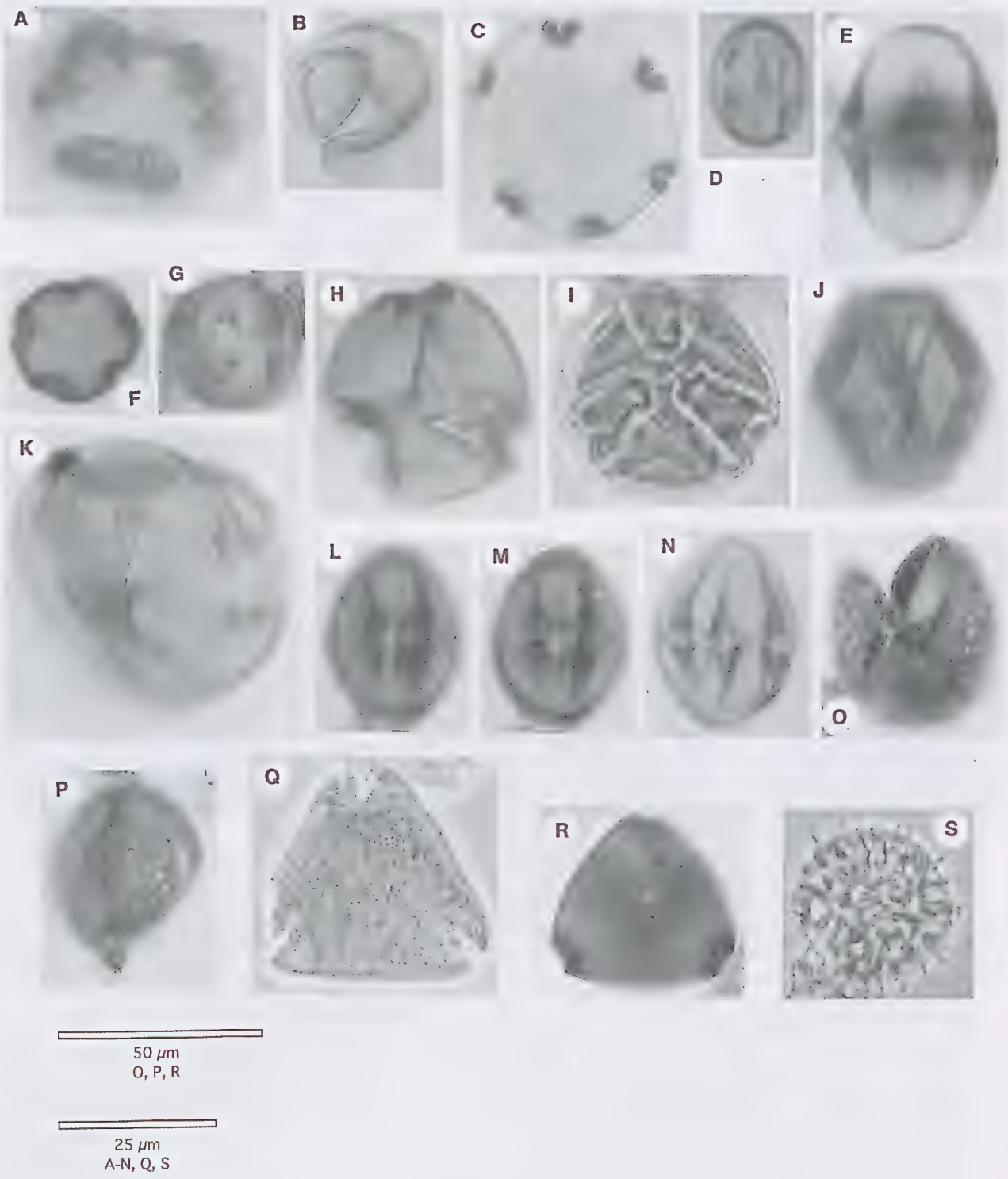

PLATE 4

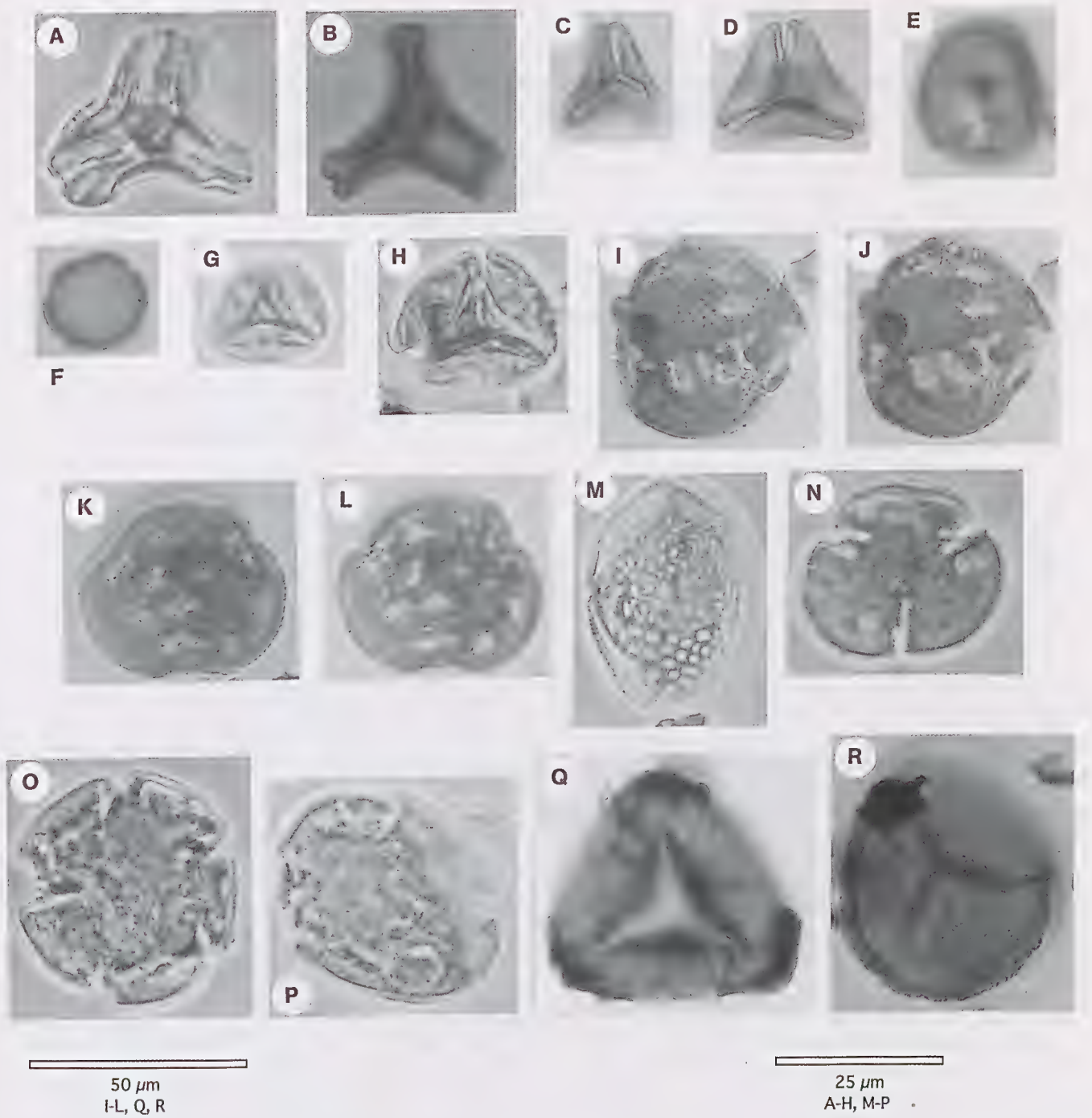

PLATE 5

Climbers, herbs, ferns and fern allies. (A) Gothanipollis perplexus *Pocknall & Mildenhall, 1984 — Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone; (B)* Gothanipollis *sp. cf.* G. gothani *Krutzsch, 1959 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (C)* Gothanipollis *sp. cf.* G. bassensis *Stover & Partridge, 1973 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (D)* Tricolpites simatus *Stover & Partridge, 1973 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (E)* Tricolpites trioblatus *Mildenhall & Pocknall, 1989; equatorial view — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (F)* Stephanocolpites oblatus *Martin, 1973 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (G)* Striasyncolpites laxus *Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (H)* Striasyncolpites laxus *Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (I–J) Droseraceae; ×788 — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (K–L) Droseraceae; ×788 — Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone; (M)* Liliacidites *sp.; phase contrast — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (N)* Tricolpites reticulatus *Cookson ex Couper* emend. *Jarzen & Dettmann, 1989; phase contrast — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (O)* Retistephanocolpites *sp. aff.* Callitriche *(Callitricheaceae) — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (P)* Stephanocolpites sphericus *(Couper) Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (Q)* Ischyosporites *(al.* Klukisporites*)* lachlanensis *Martin, 1973; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (R)* Latrobosporites marginis *Mildenhall & Pocknall, 1989; × 788 — Lemonthyme DH 5825 at 24.7 m,* P. tuberculatus *Zone.*

THE IDENTIFICATION AND DISTRIBUTION OF *GLYCINE LATROBEANA* (MEISSN.) BENTH. IN TASMANIA

by A.J.J. Lynch

(with two tables and one text-figure)

Lynch, A.J.J., 1994 (30:vi): The identification and distribution of *Glycine latrobeana* (Meissn.) Benth. in Tasmania. *Pap. Proc. R. Soc. Tasm.* 128: 17–20. ISSN 0080–4703. Department of Geography and Environmental Studies, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001 (formerly of Parks and Wildlife Service, Department of Environment and Land Management, Hobart).

Glycine latrobeana has commonly been confused in Tasmania with other *Glycine* species and also with *Desmodium gunnii*. This paper details the known distribution and habitat characteristics of *G. latrobeana* and presents a key to the species of *Glycine* extant in Tasmania.
Key Words: Fabaceae, Glycine, Tasmania.

INTRODUCTION

Three species of *Glycine* occur in Tasmania: *G. clandestina* J.Wendl., *G. latrobeana* (Meissn.) Benth. and *G. microphylla* (Benth.) Tind. These species are all small, perennial, trifoliolate herbs, which may become trailing or twining if protected from grazing. Like many leguminous plants, they are palatable, and the species are restricted to dry sclerophyll woodlands where the populations are usually grazed by native herbivores. Consequently, wild plants tend to be small, comprising only a few short stems (up to 0.1 m length). In Tasmania, the three *Glycine* species can adopt similar habits, even if not intensively grazed, making identification difficult.

Glycine latrobeana has commonly been confused in Tasmania with the other *Glycine* species and also with *Desmodium gunnii*. Similar confusion within the *Glycine* genus has been noted in South Australia (Davies 1986). In Tasmania, this confusion has arisen from identifications based on growth habit as described in Curtis & Morris (1975). These authors recognised only *G. clandestina* and *G. latrobeana* as present in Tasmania, and did not describe the variability inherent in *G. clandestina*. In addition, confusion has arisen temporarily from the results of cytological studies by CSIRO. These factors have resulted in the misidentification of *Glycine* species in surveys, especially the grasslands survey (Kirkpatrick *et al.* 1988), and in the literature (Duncan & Harris 1983, Kirkpatrick *et al.* 1991). As a result, the extent of *G. latrobeana* in Tasmania has been overestimated. This paper details the known distribution and habitat characteristics of *G. latrobeana*, and presents a new key for distinguishing between species of *Glycine* extant in Tasmania. Nomenclature of plant species follows Buchanan *et al.* (1989), except for *Desmodium gunnii* (syn. *Desmodium varians* var. *gunnii*) which follows Hacker (1990).

IDENTIFICATION

The morphology of *G. latrobeana* was described in a revision of the genus and its immediate allies (Hermann 1962). Field identification of *Glycine* species is difficult because they are usually grazed, because they lack flowering or fruiting characters for much of the year, and also because of their ability to reproduce via both chasmogamous and cleistogamous inflorescences. *G. tabacina* has also been thought to occur in Tasmania, but has not been positively identified (J. Grace & A. Brown, pers. comm.). The following section on identification is based on Tindale (1987), Jessop & Toelken (1986), J. Grace & A. Brown (pers. comm.) and personal observations.

A key to the four species of *Glycine* is presented in table 1, based on the stem, stipel, leaf and seed morphology. Additional characters distinguishing *G. latrobeana* from *G. clandestina* are that the former has trailing rather than twining stems, that it may spread rhizomatously, and also that it has orbicular to obovate leaflets rather than digitately trifoliolate leaflets (however, this characteristic is highly variable in Tasmanian specimens of *G. clandestina*, which may also have orbicular leaflets, especially when stems are young).

The chasmogamous flowers of the *Glycine* species are small, either purple or pink pea-flowers ascending in racemes from the axils of the upper leaves on long peduncles. Cleistogamous flowers are often solitary, frequently in the lower axils, and on very short peduncles. These flowers do not open but self-fertilise. The inflorescence of *G. latrobeana* is more compact than *G. clandestina*, being crowded near the ends of the peduncles rather than spread along the upper half. The pods of *G. latrobeana* are about 20–25 mm by 5 mm and contain 3–5 cylindrical-shaped seeds, whereas the pods of *G. clandestina* are c. 12–30 mm by 3–4 mm and contain 4–8 seeds (Weber 1986).

Desmodium gunnii is similar in appearance to *G. latrobeana* but is distinguishable by its hairless stems and lobed pod.

DISTRIBUTION

Glycine latrobeana is an uncommon species which usually occurs in the open grasslands of southeastern Australia (Mt. Lofty Ranges and southeastern region of South Australia, throughout Victoria except for the northwestern quarter, the far eastern section and the districts of Shepparton and Albury; Davies 1986).

Records in Tasmania older than 25 years (fig. 1) placed the species in the northwest at Circular Head (1836, 1837), and in the midlands (Folly Lagoon near Ross 1964) extending

TABLE 1
Key to Tasmanian *Glycine* Species*

1. Stems non-stoloniferous. Leaves digitately trifoliolate, the 3 leaflets equally petiolulate and subsessile (i.e. all petiolules equal lengths). Veins of leaflets coarsely reticulate within the larger areolae. Stipels of the median petiolule absent or minute. 2
1. Stems stoloniferous with adventitious roots at the nodes of above-ground stems. Growth habit prostrate and/or twining. Leaves pinnately trifoliolate, the terminal leaflet inserted on a short but distinct petiolule, lateral leaflets subsessile. Stipels always present on the median petiolule. Seeds of chasmogamous legumes 3–6, perisperm granular or smooth. Veins of the leaflets very finely reticulate within the larger areolae. 3
2. Stems elongate, growth habit twining, with shoots all from the crown. Stipels absent on the median petiolule. Stipules oblong to lanceolate. Seeds of chasmogamous legumes 9–12, with a brown-coloured, rough surface. Seeds c. 1.5 × 1–1.2 mm ..... *G. clandestina*
2. Stems short, erect, decumbent or ascending, growth habit trailing and spreading rhizomatously. Petiolules densely covered with antrorse to reflexed hairs, obscuring stipels which are minute and caducous. Stipules suborbicular to broadly ovate or reniform, as wide as long or wider, and wrapping around stem. Seeds of chasmogamous legumes 3–5, with a dark-brown, smooth to muriculate surface. Seeds c. 2–2.75 × 1.75–2.25 mm ..... *G. latrobeana*
3. Leaves weakly pinnately trifoliolate. Growth habit twining. Seeds 1.5–2.2 × 1–2 mm, perisperm smooth ..... *G. microphylla*
3. Leaves strongly pinnately trifoliolate. Growth habit trailing. Distinct, long stipules. Seeds 2–2.5 mm × 1.8–2.5 mm, perisperm smooth or in some forms granular. Not recorded from Tasmania ..... *G. tabacina*

*Adapted from Tindale 1987, Jessop & Toelken 1986 and J. Grace & A. Brown (pers. comm.)

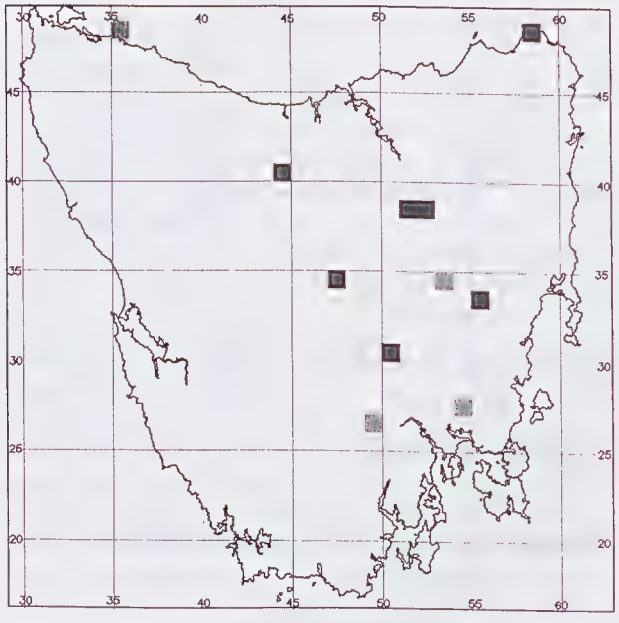

FIG. 1 — Distribution of Glycine latrobeana *in Tasmania: recently recorded populations (dark shading), records older than 25 years (paler shading).*

south to Runnymede (1848) and the Derwent Valley (Plenty 1839). None of these records has been verified recently. The current Tasmanian distribution of the species (fig. 1) appears to be in the midlands: from north of Epping Forest (Powranna Road 1991), at Stockers Bottom (1981), and at Pig Farm Hill in the Bothwell area (1982); on the central plateau, at two sites along the Ouse River (1980, 1984); and at two near-coastal sites at Cape Portland, in the far northeast of the state (1983, 1991). Specimens of *G. latrobeana* from Pig Farm Hill and the upper Ouse River were identified by CSIRO Plant Industry researchers Dr A. Brown and Dr J. Grace from field collections by Dr M. Brown and F. Duncan. Two other sites without supporting specimens have also been recorded for *G. latrobeana:* Hummocky Hills in the midlands (M. Cameron, pers. comm. 1992) and Dogs Head Hill, north of Mole Creek in northern Tasmania (Duncan 1989).

Approximately 60 *Glycine* plants were observed on private land on the Powranna Road at the northern end of Epping Forest, midlands Tasmania, in 1991. The site was very small (10 m × 5 m). It was located on a gentle slope above a poorly drained area of cleared native pasture and sedges, at an altitude of 170 m. This site faced southeast and was situated on sandy loam on dolerite, amidst a *Eucalyptus pauciflora* and *E. viminalis* open woodland with a moderately dense, shrubby understorey. The understorey was dominated by *Acacia dealbata* and *Pteridium esculentum.* The ground layer was grassy, dominated by *Themeda triandra, Poa sieberiana, Ehrharta stipoides, Stipa* sp., *Danthonia* sp. and *Aira caryophyllaea,* and also with *Lissanthe strigosa, Astroloma humifusum, Centaurium erythraea, Hypochoeris glabra, Plantago varia, Goodenia lanata, Brunonia australis* and *Pimelea humilis.* The area was grazed by sheep, and also subject to woodcutting and frequent firing. The ground species were under considerable grazing pressure, with little regeneration observed of *Brunonia australis* and none of *Glycine latrobeana* (A. Pyrke, pers. comm.). The weed gorse, *Ulex europaeus,* occurs near the site. *G. latrobeana* has also been reported to occur five kilometres to the southwest, at Hummocky Hills (M. Cameron, pers. comm.).

Two *Glycine* species have been collected in the Stockers Bottom locality. *G. clandestina* was identified from one site (A. Brown & J. Grace, pers. comm.), while one kilometre east, *G. latrobeana* has been collected. The *G. latrobeana* site was located on an undulating plateau at 420 m altitude on Triassic sediments. The community was localised and composed of a *Eucalyptus viminalis–E. dalrympleana* open

forest marginal to a *E. ovata–E. pauciflora–E. rodwayi* frost hollow. The site had a high fire frequency, reflected in the heathy grassland understorey, which was dominated by the shrubs *Acacia dealbata, Lissanthe strigosa, Acrotriche serrulata* and *Astroloma humifusum,* the grasses *Microlaena stipoides, Danthonia* sp. and *Poa rodwayi,* and the herbs *Viola* spp., *Pimelea humilis, Acaena echinata, Plantago varia* and *Bossiaea prostrata.* The site had been selectively logged and was grazed.

The site at Pig Farm Hill in the Bothwell district was also located on private land. The site was on the moderately sloping, northern aspect of a broad knoll at an altitude of 660 m. The local rock-type was Jurassic dolerite, and the soils shallow. The vegetation community was a *Eucalyptus rubida* and *E. dalrympleana* woodland with a shrubby understorey, primarily of *Acacia dealbata* and regenerating *E. rubida.* The ground cover consisted of moderately dense *Lomandra longifolia,* with *Lissanthe montana,* and a dense cover of the grasses *Poa labillardieri, P. rodwayi* and *Danthonia* sp. The herbs *Pimelea humilis, Dichondra repens, Lagenifera stipitata, Geranium potentilloides* and *Senecio minimus* were also present. This site had a frequent firing regime and was grazed by sheep.

Glycine latrobeana has been collected from a high altitude site (900 m) on the upper Ouse River, Miena district (1984). This site was a flat to undulating site on the top of a broad ridge above the river, near the Monpeelyata Canal. It comprised *Eucalyptus pauciflora* woodland over a mid-dense, low shrub layer of *Cyathodes parvifolia, Leucopogon hookeri* and *Lomatia tinctoria,* and a predominantly grassy ground cover of *Poa gunnii, Elymus scabrus, Danthonia penicillata, Deyeuxia quadriseta* and *Dichelachne rara.* The following herbs also contributed cover: *Plantago paradoxa, Acaena novae-zelandiae, A. echinata, Geranium sessiliflorum* and *Glycine clandestina.* The local geology was dolerite, and the site was fired at reasonably frequent intervals.

Closer to the Ouse River and near Remarkable Rock, *G. latrobeana* has been collected in flower and fruit (1980). This site was located in small meadows above the river at an altitude of 850 m.

Two collections of this species have been made close to sea level at Cape Portland, in the far northeast of Tasmania. The first site was located on the neck of the Cape Portland headland (1983). *Glycine* was, however, extremely rare. It was located in pasture dominated by *Zoysia, Trifolium, Cerastium, Plantago* and *Lomandra.* The second site (1991) was located 4 km farther south, at Petal Point. *G. latrobeana* was localised and growing in sandy soil on a grassy flat.

One record exists of *G. latrobeana* at Dogs Head Hill, north of Mole Creek, on limestone at about 350 m elevation (Duncan 1989). This population was not relocated in late January 1992, although *G. microphylla* and *D. gunnii* were collected. *G. latrobeana* may still be present at the site, since these two *Glycine* species are in coexistence on the Upper Ouse River; it was described as common on the north-facing lower and mid-slopes amidst grassy *Eucalyptus amygdalina* woodland (Duncan 1989). These slopes were frequently fired. The low-to-medium understorey was dense and included *Acacia dealbata, A. melanoxylon, Pultenaea juniperina, Lomatia tinctoria, Bossiaea riparia* and *Acrotriche serrulata.* The ground layer was also dense, comprising *Pteridium esculentum, Lomandra longifolia, Lepidosperma laterale, Dianella* sp. and the grasses *Elymus scabrus, Danthonia pilosa, Themeda australis, Poa* sp., *Ehrharta stipoides, Dichelachne rara* and *Deyeuxia quadriseta.*

The preferred habitat of *G. latrobeana* appears to be on well-drained and insolated sites with a dolerite substrate or sandy soils, usually on flats or gentle slopes of plains, ridgelines, or valleys (table 2). The sites vary from near sea level to 900 m altitude, but tend to be in dry sclerophyll, shrubby woodland, often with a dense grass component of the ground layer, and dominated by *Eucalyptus viminalis, E. pauciflora* or *E. dalrympleana.* The species may also occur in grasslands. Some overstorey cover appears to be required in the midlands populations, so a balance must be achieved between regeneration of canopy species with maintenance of an open shrubby to grassy understorey.

Its regeneration ecology appears to be typical of dry sclerophyll species. The species produces hard seeds, which may join the soil-stored seed bank and germinate after mild to hot fires. *G. latrobeana* may also resprout, a characteristic enhanced by its thickened tap-root. This tap-root enables the species to lie "dormant" through winter, and reshoot, flower and fruit in late spring to early summer. The timing of grazing is, therefore, very important to the survival of this species. Although the seed persists in the soil, spring–summer grazing over many years combined with frequent firing will deplete the seed bank and the capacity of the species to persist. The seed has a high viability and probable longevity but is not known to be easily or commonly dispersed. The sites are usually very localised, and most are subject to frequent firing and grazing. All sites are, therefore, important to the survival of the genetic diversity of this species in Tasmania.

CONSERVATION STATUS OF *GLYCINE LATROBEANA*

Glycine latrobeana was listed nationally as rare (3RCa), with a distribution over more than 100 km, and considered adequately reserved (Briggs & Leigh 1988). More populations have been found in Victoria (J. Grace, pers. comm.), but the species is still considered nationally to be vulnerable (ANZECC 1993). In Tasmania, there are seven populations recently recorded, two of which need to have specimens collected for the Tasmanian Herbarium. There are also two other sites which need to be confirmed. The sites are widespread but extremely restricted, usually over areas tens of metres across. They also tend to contain less than 60 plants at a site. The species is unreserved and should be upgraded from rare (r3 – Kirkpatrick *et al.* 1991) to vulnerable at both the state and national levels (Vuv – Lynch 1993).

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TABLE 2
Summary of habitat records and conservation information for *Glycine latrobeana*

Recent records:	7 (– 9) extant sites	
Habit:	Small, perennial trifoliolate herb, trails across ground if protected from grazing	
Population size:	< 500	
Regeneration:	Type:	Presumed from soil-stored seed, not observed
Habitat:	Landform:	(Flat ridgetops) — gentle slopes of plains, ridgelines, valleys
	Altitude:	Near sea level–900 m
	Aspect:	North to southeast
	Slope:	Gentle (usually < 10°)
	Community:	Dry sclerophyll shrubby to grassy woodland (*Eucalyptus viminalis, E. pauciflora, E. dalrympleana*), may be in pasture
Fire response:	May resprout; significant seed germination of *G. clandestina* after moderate intensity burns (Auld & O'Connell 1991)	
Conservation status:	Recommended:	Vuv
	Current:	(V – ANZECC 1993; r3 – Kirkpatrick *et al.* 1991; 3RCa – Briggs & Leigh 1988)
Comment:	Unreserved	
	Herbarium specimen not collected from site at Dogs Head Hill, Mole Creek (proposed reserve), and population may actually have been *G. microphylla*	

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Selected Glossary

(adapted from Curtis & Morris 1975)

areolae:	spaces, usually angular, marked out on a surface by ridges or cracks
caducous:	falling at an early stage or prematurely
chasmogamous:	of flowers which are cross-pollinated
cleistogamous:	of flowers which are self-fertilised
petiolule:	the stalk of a leaflet
stipel:	one of a pair of outgrowths that may occur at the base of a leaflet stalk, i.e. stipule of a leaflet
trifoliolate:	having a compound leaf or leaves each with three leaflets

VARIATION IN *EUCALYPTUS BARBERI* L. JOHNSON & BLAXELL

by A.C. McEntee, B.M. Potts and J.B. Reid

(with three tables and four text-figures)

McEntee, A.C., Potts, B.M. & Reid, J.B., 1994 (30:vi): Variation in *Eucalyptus barberi* L. Johnson & Blaxell. *Pap. Proc. R. Soc. Tasm.* 128: 21–30. ISSN 0080–4703. Department of Plant Science, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001.

Phenetic variation within *Eucalyptus barberi* L. Johnson & Blaxell was examined and compared to related Tasmanian species. "Typical" northern populations were morphologically distinct from the more diverse group of populations to the south. This phenetic disjunction did not correspond to the major geographic disjunction in the range of *E. barberi*. Detailed study of two morphologically aberrant populations indicated that they probably arose from *in situ* hybridisation; however, the exact identities of the progenitor species remains unclear. The type locality and several of the "southern" populations, as well as aberrant populations at Meredith Tier and Ponybottom Creek, deserve formal conservation.

Keywords: *Eucalyptus barberi*, genetic variation, hybridisation, rare endemic, conservation, Tasmania.

INTRODUCTION

The past environment of the east coast is less well understood than that of other regions of Tasmania (e.g. southwestern Tasmania, MacPhail & Colhoun 1985). In addition, the Eastern Tiers have received little botanical study until relatively recently (Duncan *et al.* 1981, Kirkpatrick 1981). Kirkpatrick & Brown (1984b) suggested that the geographic and habitat patterns of many species on the east coast result from limited radiation from separate glacial refugia. Their study of endemism in Tasmania suggested two centres of endemism on the east coast, implying at least two past glacial refugia (Kirkpatrick & Brown 1984b).

Eucalypts in this region exhibit interesting biogeographic and genetic patterns of uncertain origin. These include unexplained north–south range disjunctions (e.g. *Eucalyptus tenuiramis* – Wiltshire *et al.* 1991), absences from apparently suitable habitats in the northeastern mountains (*E. coccifera, E. urnigera, E. subcrenulata* and *E. johnstonii* – Potts 1990), and the unlikely presence of high-altitude species on low-altitude hills (*E. coccifera* – Shaw *et al.* 1984). In addition, species that are morphologically and ecologically distinct in the southeast appear to converge in both morphology and substrate preference in the east (*E. pulchella, E. amygdalina* and *E. tenuiramis* – Kirkpatrick & Brown 1984b). Other species exhibit marked genetic differentiation between eastern and southeastern populations (e.g. *E. cordata* – Potts 1989), and patches comprising individuals outside the typical phenotypic range of currently described species are regularly encountered (e.g. Potts 1989, Potts & Reid 1985b).

The present study examines population differentiation in the rare Tasmanian endemic *E. barberi*, that is distributed as a series of small, disjunct populations on the east coast of Tasmania (Kirkpatrick 1981, Pryor & Briggs 1981). In addition, several small, variable populations with some affinity to *E. barberi* are examined. *E. barberi* is restricted to the northern slopes of dry, low-altitude, dolerite ridges, most of which are unreserved crown or private land (Duncan 1989). *E. barberi* was first described informally by Barber (1954). It was formally described by Johnson & Blaxell (1972), who considered that it had obvious affinities to *E. ovata, E. camphora* and *E. yarraensis* and therefore placed it in the informal subseries *Ovatinae* (series *Ovatae*, section *Maidenaria*, subgenus *Symphyomyrtus*) of Pryor & Johnson (1971). Ladiges *et al.* (1981, 1984) included one population in phylogenetically oriented studies of juvenile and seedling characters within the series. Chippendale (1988) has since redefined the series *Foveolatae*, which also includes *E. aggregata, E. rodwayi* and *E. brookeriana* (Gray 1979). The affinities of *E. barberi* to other Tasmanian *Foveolatae* species are also examined.

MATERIALS AND METHODS

Sampling

Sites were chosen that encompassed the full geographic range of *E. barberi* (fig. 1, table 1), including the type locality (east Cherry Tree Hill; site 4). Representative samples of the other Tasmanian *Foveolatae* species (*E. brookeriana* A.M. Gray, *E. ovata* Labill. and *E. rodwayi* Baker & Smith) were also included for comparison with *E. barberi*.

Atypical phenotypes with some affinities to *E. barberi* grow at Meredith Tier (sites 10–11) and Ponybottom Creek (sites 12–13). At Meredith Tier, samples were located along a transect (4–8 trees from each of 7 sites) to capture a distinct spatial gradient of atypical phenotypes over about 1 km. Eleven trees were also sampled from an isolated stand, with apparent affinities to *E. barberi*, 1 km away (site 6). There was no evident spatial pattern of phenotypes at Ponybottom Creek. Consequently ten trees were sampled, in each of three subjective classes:
(1) narrow green foliage, resembling *E. barberi* (site 12),
(2) glaucous, broad-leaved phenotypes with apparent affinities to *E. gunnii* or *E. cordata* (site 13), and
(3) phenotypes intermediate between these extremes.
Nine trees were sampled from the nearest population with affinities to *E. barberi* (Ringrove Razorback, site 9), 1.5 km away. A range of eastern populations of *E. cordata, E. gunnii, E. archeri, E. johnstonii* and *E. subcrenulata* were sampled, including those proximal to the Meredith Tier (sites 10–11) and Ponybottom Creek (sites 12–13) sites, because

TABLE 1
Populations sampled for this study

Species	Sample location	Site code	AMG ref.* East	AMG ref.* North	Alt†. (m)	Popn‡ (min)	Number sampled§ AP	JP	AH	JH
Eucalyptus barberi	Blindburn Hill North	1	6022	53678	220	400	12	22	12	22
	Blindburn Hill South	2	6024	53663	200	30	11	24	11	24
	Cherry Tree Hill West	3	5943	53528	180	40	9	23	9	23
	Cherry Tree Hill East	4	5948	53518	170	60	12	16	12	16
	Brushy Creek	5	5762	53478	440	60	10	18	10	18
	Meredith Tier	6	5770	53297	400	30	11	35	–	–
	Lily Flats (South of)	7	5718	53161	320	60	13	25	13	25
	Ravensdale Hill	8	5713	53079	140	18	9	22	9	22
	Ringrove Razorback	9	5735	52713	160	30	9	21	–	–
Uncertain	Meredith Tier green	10					7	29	7	29
	intermediate	–	5767	53301	440	200	–	–	25	96
	glaucous	11					6	37	6	37
	Ponybottom Ck green	12					10	37	10	37
	intermediate	–	5736	52723	180	60	–	–	13	42
	glaucous	13					10	41	10	41
E. brookeriana	Buckbys Road	14	3633	54602	120	–	4	–	–	–
	Elephant Pass	15	6020	53908	390	–	–	4	–	–
	E. brookeriana type ¶	16	5705	53420	600	–	1	1	–	–
	Rocka Rivulet	17	5700	53205	450	–	2	5	–	–
	Kellevie Plateau	18	5670	52663	340	–	1	5	–	–
Pooled *E. brookeriana*		BR	sites: 14 – 18			–	8	18	–	–
E. ovata	Robbins Road	19	3210	54855	20	–	5	–	–	–
	Bass Highway	20	3990	54575	10	–	6	–	–	–
	W Road	21	5727	52758	40	–	8	13	–	–
	Hobart College	22	5250	52480	280	–	9	15	–	–
Pooled northwest coast *E. ovata*		WO	sites: 19 – 20			–	8	13	–	–
E. rodwayi	Steppes	23	4910	53375	800	–	–	19	–	–
	M Road South	24	5698	53233	580	–	7	12	–	–
E. cordata	Bluestone Tier	25	5652	52932	350	–	10	18	10	18
	Brown Mt	26	5428	52837	710	–	7	13	7	13
	Perpendicular Mt top	27	5933	52766	340	–	–	–	10	–
	Perpendicular Mt low	28	5930	52765	240	–	–	–	10	–
	Square Mt	29	5506	52695	370	–	9	6	9	6
	Hospital Creek	30	5673	52660	240	–	–	–	10	–
	Chimney Pot Hill	31	5225	52476	430	–	–	–	10	–
	Cape Queen Elizabeth	32	5345	52109	100	–	–	–	10	–
E. archeri	Mt Maurice	33	5490	54260	1000	–	–	13	–	13
E. gunnii	Mt Arthur NE	34	5208	54283	500	–	–	–	10	–
	Mt Victoria	35	5687	54228	790	–	–	–	20	–
	Snow Hill	36	5693	53592	950	–	–	–	25	15
	Pensford	37	4837	53487	960	–	–	–	20	–
	M Road North	38	5732	53298	640	–	11	32	11	32
E. johnstonii	Springs, Mt Wellington	39	5190	52490	600	–	–	10	–	–
	Snug Plains	40	5133	52330	600	–	–	5	16	–
E. subcrenulata	Dove Lake	41	4135	53870	960	–	–	12	–	–
	Lake Charles	42	4367	53633	1070	–	–	10	–	–

* Australian Map Grid reference. † Altitude (metres). ‡ Minimum estimate of population size for *E. barberi* populations.
§ Number of individuals sampled for population studies: variation in *E. barberi* and related species (AP = adults, JP = juveniles); aberrant populations at Meredith Tier and Ponybottom Creek, sites 10–13 and intermediates (AH =adults, JH = juveniles).
¶ Seed collected from open pollinated offspring from type specimen of *E. brookeriana*, grown as an ornamental.

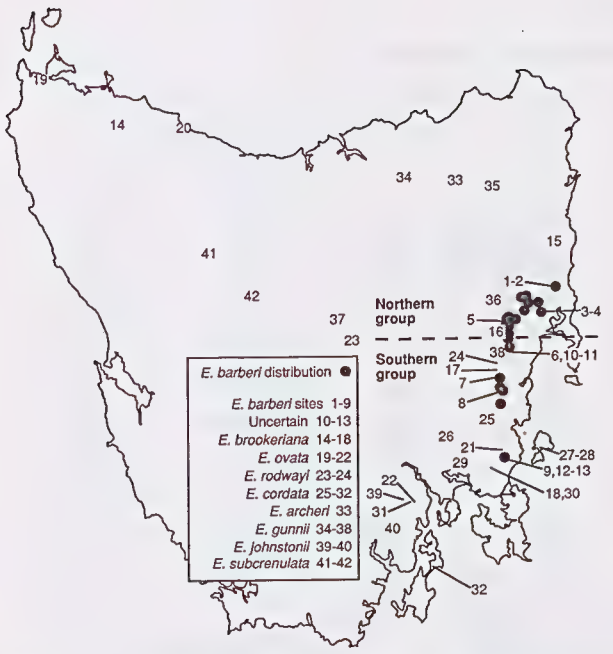

FIG. 1 — The known distribution of Eucalyptus barberi *(• — from Forestry Commission of Tasmania records) and locations of populations of all species sampled for this study (codes). (Location codes are detailed in table 1.) An explanation of "northern" and "southern" groups is given in the discussion.*

some atypical phenotypes showed affinities to these species. Adult data from previous studies were also used for *E. gunnii*, *E. archeri* (Potts & Reid 1985b) and *E. cordata* (Potts 1989). Open-pollinated seed, as well as three typical, mature canopy leaves and capsules, was collected from up to 13 trees, at least two tree-heights apart, from each *E. barberi* population (see table 1, AP).

Progeny trial

Seeds were germinated on a 1:1 vermiculite:gravel mix covered with a surface (20 mm) of vermiculite. At the cotyledonary stage (three weeks) plants were transplanted into black plastic potting bags filled with potting mix. Plants were grown under glasshouse conditions (day 19°–24°C, night 12°–14°C) with the natural photoperiod extended to 18 h by a mixed incandescent and fluorescent light source.

Four seedlings from each of approximately 12 families were used in the progeny trial and were placed in a completely random design. Between 16 and 25 individuals were scored for each typical *E. barberi* population (numbers sampled from each populations are shown in table 1, JP). *E. brookeriana* samples (sites 14–18) were pooled (BR) for the purposes of the analysis. Similarly, northwest coast *E. ovata* populations (sites 19–20) were treated as one population sample (WO).

Morphometric data collection and analysis

The characters scored from adult and juvenile plants are listed in table 2. Capsule and adult leaf characters are the same as those described in Potts & Reid (1985b). Adult data analysis was performed on the means of three replicates from each tree. Seedlings were scored six months after planting. Measurement of the juveniles was based upon characters (table 2) recognised as distinguishing *E. barberi* from other members of the *Foveolatae* (LAML8, LAMW8, LWP8, PETL8, RUG, GLAND, CREN, LATLEN, LATRAT and INTLEN), *E. johnstonii* and *E. subcrenulata* (DIARAT, COLOUR), and *E. cordata* and *E. gunnii* (LOBE8, GLAU, INTRANOD, PETNODE; Chippendale 1988). Juvenile leaf characters were measured from a leaf removed from the eighth node (counting the cotyledonary node as node 0), and stem characters from the eighth internode (below node 8). Categorical multistate characters measured on relative scales were scored by comparison with standards (GLAND, CREN, RUG, GLAU, COLOUR). DIARAT (diameter ratio = widest width/narrowest width at the same height on the stem) represented the rectangularity of the stem. INTLEN (mean internode length) was calculated as the height/ the number of internodes. LATRAT (lateral ratio = number of nodes with laterals/number of nodes) represented the proportion of the plant bearing lateral branches.

The pooled within-population residuals for each variable were tested for normality, using the UNIVARIATE procedure of SAS (SAS 1988). The relationship between residuals and fitted values, derived from the one-way GLM analysis (SAS 1988), was inspected in bivariate plots. Where necessary, transformations were used that optimised the normality and homogeneity of variance criteria. Variables and transformations used in the analysis are shown in table 2. Stepwise discriminant analysis (STEPDISC procedure of SAS) found that all variables were significant ($p < 0.05$) in separating populations.

Parametric canonical discriminant analysis was performed using the CANDISC procedure of SAS; this produced discriminant functions, which maximised the separation of populations. Means and standard errors were calculated for each population from the individual scores along the discriminant functions. The relative importance of different characters in differentiating populations, and their direction of variation in the discriminant space, were summarised by plotting vectors, the lengths of which are proportional to the univariate F-values, the directions being determined by the standardised canonical coefficients of the relevant discriminant functions. Populations were also clustered, using average linkage cluster analysis (Sneath & Sokal 1973) based on the matrix of Mahalanobis' distances. Mahalanobis' distances between populations were calculated from the squared Euclidean distance between populations, in the space defined by the first nine discriminant axes (representing 99.3% of adult and 94.9% of juvenile variation for the populations shown in fig. 3). This procedure was applied to adult and juvenile (table 1: AP, JP respectively) *E. barberi* (sites 1–9) and other *Foveolatae* populations (*E. brookeriana* – BR; *E. ovata* – WO, sites 21–22; *E. rodwayi*, sites 23–24), including the green phenotypes resembling *E. barberi* from Meredith Tier (site 10) and Ponybottom Creek (site 12). For comparison with other species, this analysis was repeated, with the addition of samples from populations of *E. johnstonii* (sites 39–40), *E. subcrenulata* (sites 41–42), *E. gunnii-archeri*

TABLE 2
Morphological characters measured for this study

Code	Description	Scale*	Trans.†	Significance‡	
Adult leaf characters				$F_{15,140}$	Pr>F
LL	Lamina length	mm	log	8.42	0.0001
LW	Lamina width	mm	log	13.9	0.0001
LWP	Length to widest point	mm	log	4.73	0.0001
PET	Petiole length	mm	log	8.93	0.0001
Adult capsule characters					
PEDI	Pedicel length	mm	log	9.39	0.0001
PEDU	Peduncle length	mm	log	6.71	0.0001
CAPL	Capsule length	mm	log	19.2	0.0001
MAXW	Capsule max. width	mm	log	13.8	0.0001
PTMW	Length to max. width	mm	log	6.69	0.0001
RIMW	Rim width	mm	square	5.18	0.0001
VPOS	Valve thickness	(1–4)	square	2.92	0.0005
VSIZE	Valve size	(1–4)	log	1.97	0.0212
Juvenile leaf characters				$F_{15,333}$	
LAML8	Lamina length	mm	–	4.85	0.0001
LAMW8	Lamina width	mm	–	13.2	0.0001
LWP8	Length to widest point	mm	–	5.81	0.0001
PETL8	Petiole length	mm	–	1.58	0.0001
LOBE8	Lobe length from leaf base to bottom of lobe	mm	–	7.63	0.0001
GLAND	Gland density on leaf	(1–4)	–	8.27	0.0001
CREN	Crenulation of margin	(1–3)	–	5.51	0.0001
Juvenile stem characters					
RUG	Rugoseness	(1–3)	log	14.7	0.0001
DIARAT	Stem rectangularity	–	–	2.53	0.0014
Juvenile whole plant characters					
INTRANOD	Node 1st intranode	–	–	10.6	0.0001
PETNODE	Node of 1st petiole	–	–	9.32	0.0001
INTLEN	Mean internode length	mm	–	7.04	0.0001
LATLEN	Length longest lateral	mm	–	4.13	0.0001
LATRAT	Lateral ratio	–	–	3.14	0.0001
GLAU	Glaucousness	(0–8)	–	3.12	0.0001
COLOUR	Max. node where anthocyanin occurs on the undersurface of the leaf 0–10 × Depth of colour (0, 1, … 3)	(0–30)	–	2.15	0.0079

* Numbers in parentheses represent relative scales.
† Transformation used.
‡ Univariate significance of variation in each character between populations in the series *Foveolatae*.

(sites 33, 36, 38), *E. cordata* (sites 25–26, 29), and the most glaucous phenotypes from Meredith Tier (site 11) and Ponybottom Creek (site 13).

For analysis of the Meredith Tier and Ponybottom Creek samples, quadratic discriminant functions were calculated for both adult and juvenile data sets, which maximised the separation between typical populations of *E. barberi* (sites 1–5, 7–8), *E. gunnii* (sites 34–38) and *E. cordata* (sites 25–32). The latter procedure takes into account the differences in variance/covariance structures between species. Mean discriminant scores and 95% confidence intervals for individuals from the reference groups were calculated. Discriminant scores for individuals from Meredith Tier (sites 10–11 and intermediates) and Ponybottom Creek (sites 12-13 and intermediates) were also calculated on the two discriminant functions derived from this analysis.

In order to determine whether an individual falls within the range of variation encompassed by each reference species (*E. barberi, E. gunnii, E. cordata*), the generalised distance of each individual tree from the centroid of each species, and its significance were calculated according to equations 5.1 and 5.2b in Orlóci (1978), using separate variance–covariance matrices for each species (and equal sample sizes). An individual was classified as falling within the range of variation encompassed by a species if the probability of obtaining the observed generalised distance due to chance alone was greater than 0.05 (i.e. the individual falls within the multivariate 95% confidence interval of the species). For each of the three reference species, the proportions of adult individuals in each population that matched the reference species phenotype were calculated, as well as the proportion of individuals whose phenotype did not match

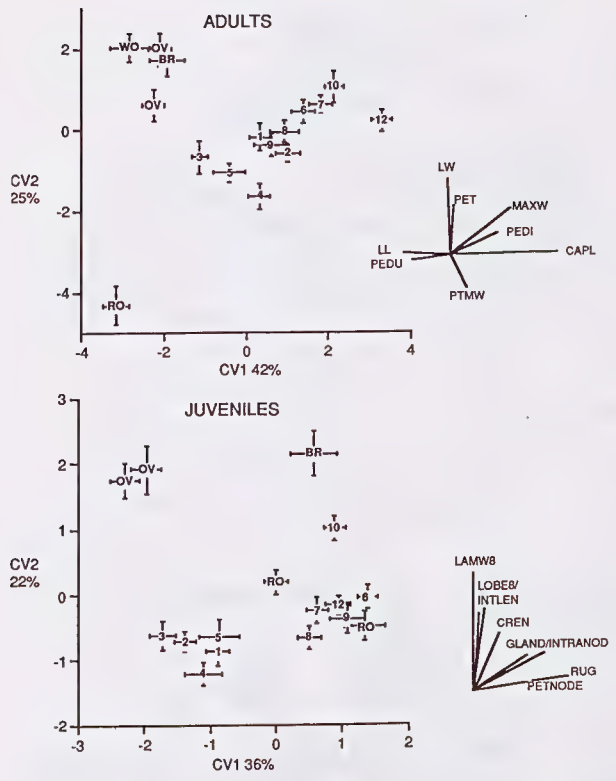

FIG. 2 — Population means and standard errors along the two major discriminant functions (CV1, CV2) derived from the analysis of adult (upper) and juvenile (lower) population samples from northern (sites 1–5) and southern (sites 6–9) populations of Eucalyptus barberi, E. brookeriana *(BR),* E. ovata *(OV, WO),* E. rodwayi *(RO) and green phenotypes resembling* E. barberi *from Meredith Tier (site 10) and Ponybottom Creek (site 12). Vectors represent the direction (derived from the standardised discriminant function coefficients) and magnitude (derived from the univariate F-values) of variation in characters between populations. The percentage of the total variance explained by each discriminant function is indicated. (Location codes detailed in table 1.)*

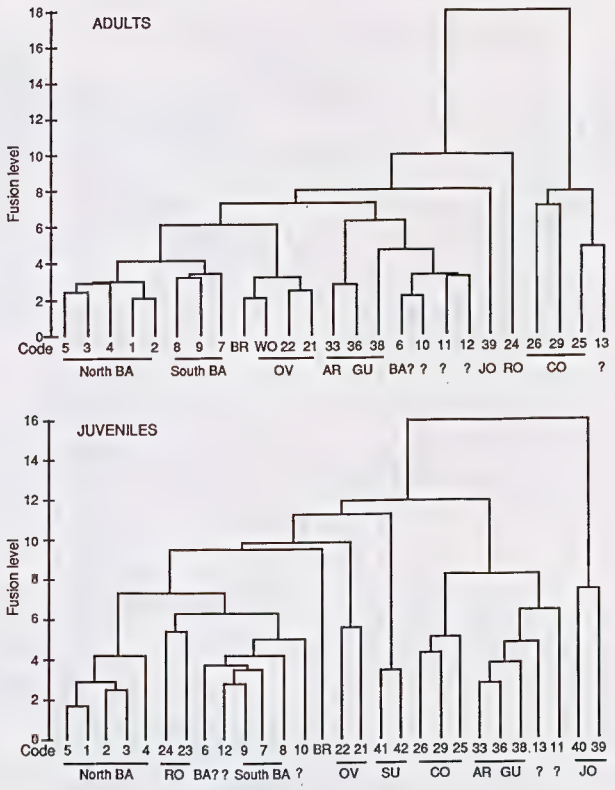
ADULTS
Fusion level
Code 5 3 4 1 2 8 9 7 BR WO 22 21 33 36 38 6 10 11 12 39 24 26 29 25 13
North BA
South BA
OV
AR GU
BA? ? ? ? JO RO
CO
?
JUVENILES
Fusion level
Code 5 1 2 3 4 24 23 6 12 9 7 8 10 BR 22 21 41 42 26 29 25 33 36 38 13 11 40 39
North BA
RO BA? ? South BA ?
OV
SU
CO
AR GU ? ?
JO

FIG. 3 — Dendrogram from average linkage clustering of adults (upper) and juveniles (lower) from populations of Eucalyptus barberi *(BA),* E. brookeriana *(BR),* E. ovata *(OV),* E. rodwayi *(RO),* E. archeri *(AR),* E. gunnii *(GU),* E. cordata *(CO),* E. johnstonii *(JO),* E. subcrenulata *(SU) and aberrant populations (?). (Location codes detailed in table 1.)*

any of the three species. Where there is phenetic overlap between species, some individuals may fall within the 95% confidence intervals of more than one species; hence, the proportions may sum to more than 100%. In the juveniles, only the proportion that matched the phenotype of *E. barberi* was calculated, since samples sizes of juvenile *E. gunnii* and *E. cordata* were insufficient to represent the species' full phenetic ranges.

RESULTS

The mean scores of the series *Foveolatae* populations on the first two discriminant axes derived from the adult and juvenile data are shown in figure 2. Clusters produced from this analysis proved to be subsets of those produced by the analysis including other species (fig. 3).

E. barberi (sites 1–9) and green samples from Meredith Tier and Ponybottom Creek with apparent affinities to *E. barberi* (sites 10, 12) were well separated from the other *Foveolatae* species (BR, OV, WO, RO) in the discriminant space derived from the analysis of adult morphological traits. However, they were not well differentiated from *E. rodwayi* (RO) in the juvenile analysis (figs 2 & 3). *E. ovata* (OV, WO) was quite distinct from *E. barberi* and *E. rodwayi* (RO) in adult and juvenile morphology. *E. brookeriana* is closer to *E. ovata* in adult morphology, particularly the northwestern samples (WO, fig. 3), but equidistant and distinct from other species in juvenile morphology.

On juvenile morphology, *E. barberi* populations fell into two distinct groups: sites 1–5 and sites 6–9, 10, 12 (fig. 3). These correspond geographically to a northern and a southern group (fig. 1). In the cluster analysis, which incorporates a larger proportion of variation than the ordination, this pattern is also apparent in the adults (fig. 3). Southern populations (sites 6–9, 10, 12) exhibited greater variation in adult than juvenile morphology. In particular, the green samples with apparent affinities to *E. barberi* from Meredith Tier (sites 6, 10) and Ponybottom Creek (site 12) were separated from other southern populations of *E. barberi* (fig. 3). The northern and southern *E. barberi* populations differed in capsule traits (larger, more pedicellate capsules in southern populations), and seedlings from southern populations retained the juvenile foliage longer than northern populations (expressed as higher node of first intranode and petiole; fig. 2).

At Meredith Tier (sites 10–11) and Ponybottom Creek (sites 12–13), phenotypes varied from narrow, green-leaved individuals with seven medium-sized fruit per umbel, typical of *E. barberi*, to individuals with broad, glaucous leaves and three large fruit per umbel, resembling *E. cordata.* The

TABLE 3
Comparison of samples with the phenotypic ranges of three eucalypt species*

Collected as		Code (Site)		Classification†				
				E. barberi %	*E. cordata* %	*E. gunnii* %	None test sp. %	n
E. barberi		1	adults	100	0	17	0	12
			juveniles	100	–	–	–	22
		2	adults	100	0	18	0	11
			juveniles	96	–	–	–	24
		3	adults	100	0	0	0	9
			juveniles	100	–	–	–	23
		4	adults	100	0	0	0	12
			juveniles	94	–	–	–	16
		5	adults	100	0	0	0	10
			juveniles	83	–	–	–	18
		6	adults	45	0	27	36	11
			juveniles	63	–	–	–	35
		7	adults	100	0	8	0	13
			juveniles	92	–	–	–	25
		8	adults	100	0	11	0	9
			juveniles	91	–	–	–	22
		9	adults	89	0	11	11	9
			juveniles	86	–	–	–	21
Meredith Tier	green	10	adults	57	0	43	29	7
			juveniles	59	–	–	–	29
	intermediate	–	adults	43	0	30	44	23
			juveniles	27	–	–	–	96
	glaucous	11	adults	13	0	13	88	8
			juveniles	14	–	–	–	37
Ponybottom Ck	green	12	adults	30	0	40	50	10
			juveniles	51	–	–	–	37
	intermediate	–	adults	0	0	0	100	13
			juveniles	45	–	–	–	42
	glaucous	13	adults	0	10	0	90	10
			juveniles	12	–	–	–	41
Summary:								
E. barberi		all	adults	93	0	10	5	96
			juveniles	88	–	–	–	206
E. cordata		all	adults	0	100	0	0	76
			juveniles	0	–	–	–	37
E. gunnii		all	adults	11	0	96	3	76
			juveniles	7	–	–	–	46
Meredith Tier		all	adults	39	0	30	50	38
			juveniles	30	–	–	–	162
Ponybottom Ck		all	adults	9	3	12	82	33
			juveniles	36	–	–	–	120

* The percentage of individuals in each sample which were not significantly different ($p > 0.05$) from *E. barberi*, *E. cordata* and *E. gunnii*, and the percentage matching none of the reference species. The percentage of individuals of the reference species which were not significantly different from the reference groups is shown, for comparison with samples from Meredith Tier and Ponybottom Creek. Dash (–) indicates sample not tested. Due to overlap between reference groups, percentage may not total 100%.
† Based on generalised distance.

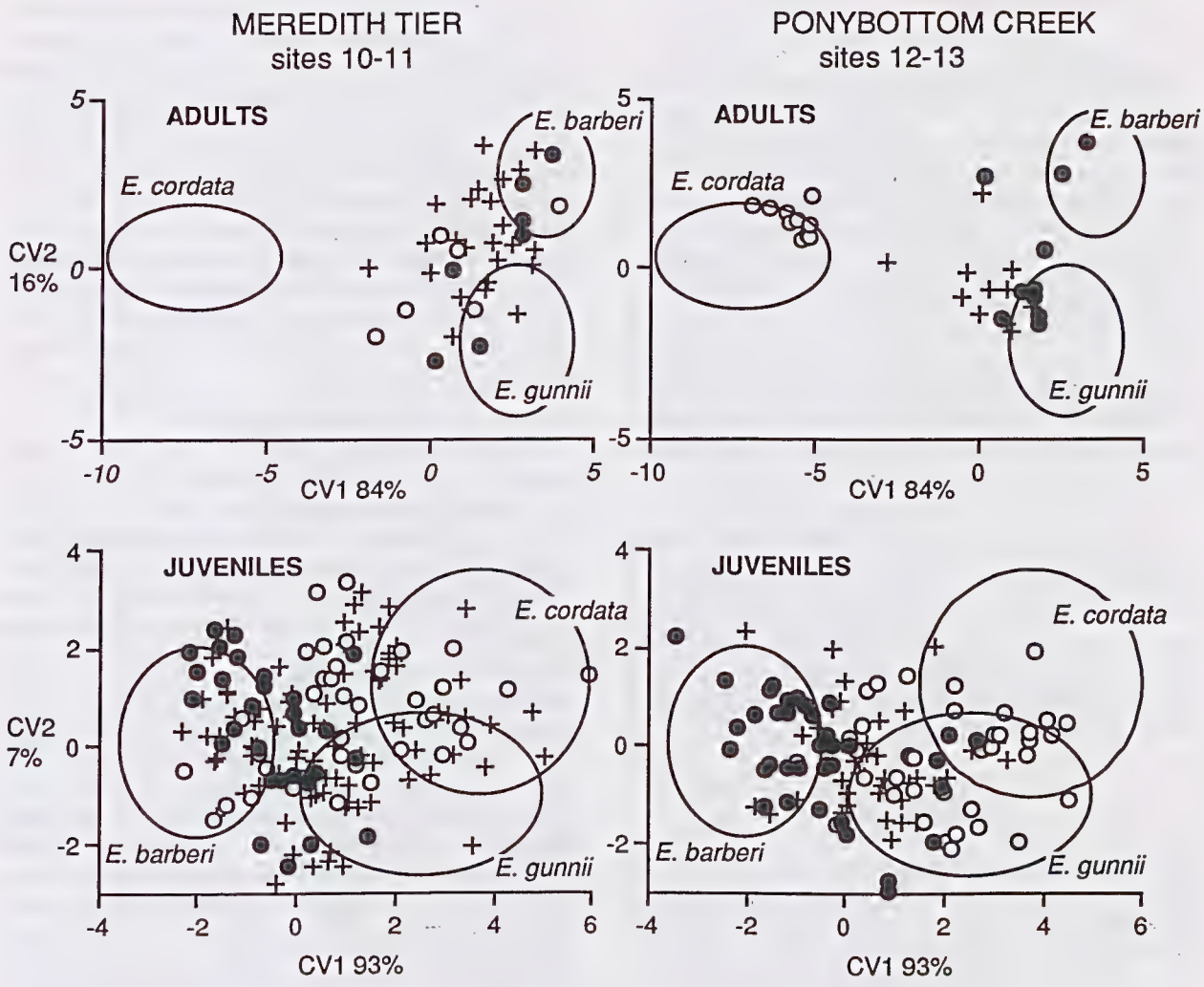

FIG. 4 — Plots of adults (upper) and juveniles (lower) from Meredith Tier (left) and Ponybottom Creek (right) on the axes derived from the discriminant analysis of typical Eucalyptus barberi, E. cordata *and* E. gunnii *samples. The percentage of variance represented by each discriminant function is shown. Ellipses represent the 95% confidence intervals for individuals of the three reference species.* ● *– green adults resembling* E. barberi *(upper), and their juvenile progeny (lower).* ○ *– glaucous adults and their juvenile progeny.* + *– intermediate adults and their juvenile progeny.*

slightly isolated populations at Meredith Tier (site 6) and Ringrove Razorback (site 9) resembled *E. barberi* in leaf characters, but varied in bud number, from three to seven per umbel. *E. gunnii*, which occurs in the vicinity of the Meredith Tier population, has narrow adult leaves similar to *E. barberi*, but has three small buds per umbel.

Samples from Meredith Tier and Ponybottom Creek were ordinated in the discriminant space differentiating core populations of *E. barberi*, *E. cordata* and *E. gunnii* (fig. 4). Overlap of the juvenile discriminant scores of the reference *E. cordata* and *E. gunnii* populations (fig. 4, ellipses) indicates that these species were less distinct from one another in the juvenile than adult stages. Tests of the significance of the generalised distance between individuals and the centroids of the three reference species are shown in table 3. It is expected, in theory, that 95% of typical species' samples would not differ significantly from the corresponding reference group. In this case, 93–100% of adults of the three species and 88% of *E. barberi* juveniles were correctly classified. There was some overlap in the ranges of *E. barberi* and *E. gunnii* adults, with 8–10% of adults of both species falling within the 95% confidence intervals of the other species.

The pattern observed for the reference populations contrasts markedly with the classification results from the anomalous populations at Meredith Tier and Ponybottom Creek. Most adults from Meredith Tier fell outside the 95% confidence intervals of all three reference species; 50% overall and 88% of the glaucous individuals were outside the confidence intervals of all the reference species (table 3). Those that did match were similar to *E. barberi* and *E. gunnii* in approximately equal proportions (39% and 30% respectively) and, overall, the Meredith Tier population showed similarities to *E. gunnii* in the cluster analysis (fig. 3). The adults from Meredith Tier deviated slightly toward, but were not within the phenotypic range of *E. cordata* (fig. 4). A large proportion of the juveniles from Meredith Tier were also outside the ranges of all three reference species and most were intermediate between the reference species (fig. 4). Cluster analysis of the juveniles placed the green sample

from Meredith Tier (site 10) as an outlier to the *E. barberi* populations and the glaucous sample (site 11) closest to *E. gunnii* (fig. 3).

In the full multidimensional space, 82% of the Ponybottom Creek adults were outside the 95% confidence intervals of all three reference species (table 3), with a small proportion of the remainder ascribed to each species. The green individuals (site 12) were divided between *E. barberi* (30%) and *E. gunnii* (40%). Only one individual from the intermediate and glaucous (site 13) samples matched a reference species (*E. cordata*), but the glaucous individuals appeared closest to the *E. cordata* populations in the cluster analysis (fig. 3), and were very close to the adult phenotype of *E. cordata* (fig. 4). A greater proportion of Ponybottom Creek juveniles matched the phenotype of *E. barberi* (36%) compared with the adults (9%, table 3). Most juveniles appeared intermediate between *E. barberi* and *E. gunnii*, but there was overlap with, and deviation toward the phenotypic range of *E. cordata* (fig. 3).

The range of variants observed in the juvenile progeny from both Meredith Tier and Ponybottom Creek (from all phenotypic classes collected) and the intermediate phenotypes of the parents strongly suggested parental heterozygosity rather than simple outcrossing. For example, recombination of leaf shape and glaucousness was very apparent in progeny of one intermediate individual from Meredith Tier.

DISCUSSION

Significant differentiation, in both adult and juvenile characters, was found between most populations of *E. barberi*. A seedling trial clearly indicated that this differentiation has a strong genetic basis. There appeared to be a primary division between a northern group of populations that may be designated "typical" *E. barberi* and other, southern, populations which deviated toward the phenotype of other species (fig. 1). There was no clear clinal or consistent spatial pattern of variation within each group. The "typical" group comprised populations from Cherry Tree Hill (sites 3–4), Brushy Creek (site 5) and the vicinity of Blindburn Creek (sites 1–2, in the Douglas-Apsley National Park). Within this group, phenetic distance was poorly correlated with geographic distance. The southern group comprised *E. barberi* populations from Ravensdale Hill (site 8), 1.5 km south of Lily Flats (site 7) and the green phenotypes resembling *E. barberi* from Meredith Tier (6, 10), Ponybottom Creek (site 12) and Ringrove Razorback (site 9). Some southern populations showed affinities to juvenile *E. rodwayi* but were quite distinct on adult traits. Conversely, several of the southern populations (sites 6, 10, 12) showed affinities toward *E. gunnii* in their adult morphology (fig. 3) but were clearly differentiated from *E. gunnii* and *E. archeri* on juvenile morphology. In most cases, they would also have been differentiated from these species on the basis of the number of buds per inflorescence, which was not included in the analysis (and was greater than the typical three of *E. gunnii* and *E. archeri*). They, therefore, appear to have closest affinities to *E. barberi*.

The high level of population differentiation found within *E. barberi* is typical of the population genetic structure that would be predicted by theory for a species distributed as a series of small disjunct populations (due to factors such as genetic drift – Falconer 1986) and has been observed in other eucalypt species with comparable distribution patterns (e.g. *E. caesia*, *E. pendens* – Moran & Hopper 1987; *E. crucis* – Sampson *et al.* 1988). Prober *et al.* (1990) suggest that such restricted distributions may result from recent divergence (with insufficient time for geographical radiation), barriers to dispersal (e.g. unsuitability of habitat, competition), or contraction of the range of an older species due to environmental factors (e.g. habitat specificity, climatic change). In this case, the degree and pattern of phenetic differentiation between *E. barberi* populations and the large disjunctions in its geographical range support Williams' (1990) contention that *E. barberi* is not a recently diverged species. *E. barberi* appears to be a relic species and has possibly been displaced from intervening sites by competition with more rapidly growing species.

It is only possible to speculate on the cause of differentiation in *E. barberi*. Genetic drift, localised selection, hybridisation and historical factors may all be involved. Kirkpatrick & Brown (1984a, b) and Potts & Reid (1985c) suggested that the present east coast flora may have originated from populations which differentiated in two glacial refugia. Such separation could explain differentiation of the northern and southern populations of *E. barberi*. However, the disjunct distribution of *E. barberi* does not appear to have been caused by insufficient time for radiation, as the major disjunction in the geographical distribution of *E. barberi* does not correspond to the phenetic disjunction (fig. 1). This contrasts with the coincidence of marked genetic differentiation with geographic disjunction in *E. tenuiramis* in the same area (Wiltshire *et al.* 1992). Disjunctions in the geographical distribution of *E. barberi* may not be as extensive as is shown by current records. Paucity of sampling may have occurred, due to the small population sizes (and area), inaccessibility and small size of the trees. There are, for example, unverified reports of other populations west of Triabunna (between sites 12–13 and site 8).

"Confusing intermediacy" (Kirkpatrick & Brown 1984b) is an apt description of the Meredith Tier and Ponybottom Creek populations. At both sites, the pattern of high diversity and intermediacy of parents and progeny, coupled with the high variability within some families, was consistent with a hybrid swarm, several generations old (e.g. Potts & Reid 1985a). The magnitude of the differences between extreme phenotypes was strongly suggestive of hybridisation, as was the distribution of extreme phenotypes at Meredith Tier. Although this may have been produced by disruptive selection from the gene pool of one species, no selective agency of sufficient magnitude was evident, particularly at Ponybottom Creek. At both localities, trees with close affinities to *E. barberi* appeared to be one of the parents. The exact identity of the other parent remains unclear. *E. cordata*, *E. gunnii* and possibly *E. morrisbyi* are the only plausible extant species. *E. morrisbyi* was not included in the progeny trial because of its extremely limited distribution (Wiltshire *et al.* 1990), and the fact that its juveniles would be difficult to distinguish from *E. gunnii* in hybrid combination (e.g. Potts 1989). At both Meredith Tier and Ponybottom Creek, extreme phenotypes did not resemble other members of the *Foveolatae*, and the involvement of *E. johnstonii* or *E. subcrenulata*, which has been reported from near Ponybottom Creek and on the Eastern Tiers (Brown *et al.* 1983), is unlikely, as the juveniles of these taxa are clearly differentiated from those of *E. barberi* and populations at Meredith Tier and Ponybottom Creek (fig. 3).

The unusual characteristics of the latter populations may have resulted from hybridisation between atypical populations of the species suggested. Such small, atypical populations of both *E. cordata* (Potts 1989) and *E. gunnii* (Potts & Reid 1985b) are numerous on the east coast and are still being found (e.g. *E. cordata* near Wielangta Hill, between site 12–13 and site 8). However, it remains to be ascertained whether the variation found at Meredith Tier and Ponybottom Creek and the deviation of these populations from typical *E. barberi* are due to past introgression or reflect genetic variation within *E. barberi* at these localities. Molecular techniques may best be able to resolve the identity of these populations.

Conservation status

At present one, albeit relatively large population of *E. barberi* is securely reserved, in the Douglas-Apsley National Park (sites 1–2). Another of the northern populations (Brushy Creek, site 5) is in the proposed Bluemans Creek state reserve (Williams 1989). Other populations, including the type locality (site 4), are unreserved. The type locality also contains other rare species (*Spyridium microphyllum, Helichrysum lycopodioides, Melaleuca pustulata, Cyathodes pendulosa* and *Gahnia graminifolia* – Duncan & Duncan 1984) and has been previously recommended for reservation (Duncan & Brown 1985).

There is a need to extend conservation measures to encompass the full range of variability in this species. In particular, the type locality, representatives of the southern phenetic group (e.g. "south of Lily flats" – site 7; "Ravensdale Hill" – site 8) and outlying populations such as Meredith Tier (sites 6, 10–11), Ringrove Razorback (site 9) and Ponybottom Creek (site 12-13) should be formally reserved. The latter populations are also of scientific interest. *E. barberi* populations are generally small, particularly the southern populations (table 1), which would argue for reservation of multiple representatives of each of the major phenetic groups.

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(accepted 17 November 1993)

HIGH-ALTITUDE STREAM FAUNAS IN THE MT PELION EAST–MT DORIS AREA OF TASMANIA

by Roy Swain, Mark Chladil and Caron Summers

(with four tables and four text-figures)

SWAIN, R., CHLADIL, M.A. & SUMMERS, C.R., 1994 (30:vi): High-altitude stream faunas in the Mt Pelion East–Mt Doris area of Tasmania. *Pap. Proc. R. Soc. Tasm.* 128: 31–39. ISSN 0080–4703. Department of Zoology (RS, CS) and Department of Geography and Environmental Studies (MC), University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001.

A survey was carried out of the aquatic fauna of the headwaters of two high-altitude (1170–1355 m) streams draining Mt Doris and two streams draining Mt Pelion East in Tasmania. Although the fauna above the treeline appeared to be characterised primarily by the loss of downstream fauna, three Trichoptera (*Notoperata maculata*, an unidentified genus from the Kokiriidae, and *Plectrotarsus* sp.) and one crustacean (*Neonipharguss*p.) may form part of a specialised high-altitude fauna. The amphipod *Neonipharguss*p. was collected from above the treeline only, whereas the other amphipod recorded, *Antipodeus* sp., was found at or below the treeline only. Cluster analyses enabled five habitat and three species groupings to be recognised. Since the habitat groupings were generally well defined by their physico-chemical characteristics as well as by the faunal groups, it is concluded that they reflect a genuine series of identifiable high-altitude stream habitats.
Keywords: alpine, high-altitude, stream fauna, Tasmania.

INTRODUCTION

Tasmania possesses a large proportion of Australia's high-altitude (above treeline) land yet, despite the considerable biogeographical importance attached to much of the island's aquatic fauna (e.g. Hynes & Hynes 1980, Swain *et al.* 1977, Williams 1974), no study of stream communities in a high-altitude source-stream has been carried out. Numerous studies of individual taxa have included high-altitude collections (e.g. Dean and Cartwright 1992; Hynes 1989, Neboiss 1977) but, since these works have been directed usually towards clarifying taxonomic or distributional questions, they have not led to generalisations about the faunal characteristics of subalpine streams in Tasmania. As part of the 1992 Wilderness Ecosystems Baseline Studies conducted by the Tasmanian Department of Parks, Wildlife and Heritage, we conducted a late summer survey of the fauna of four source-streams in the vicinity of Mt Pelion, within the Tasmanian Wilderness World Heritage Area in western Tasmania. Two streams were located on Mt Doris and two on Mt Pelion East, collectively representing a wide range of sub-alpine lotic habitats. In two of the streams, faunal samples were also obtained from just below the treeline but the topography made this impossible in the other two. All taxa found were collected, but the investigators had a particular interest in amphipods, syncarids and stoneflies, not only because these are relatively well known taxonomically, but also because it was considered that they are the most likely to contain species of value as high-altitude "markers", if such species exist.

METHODS

The fieldwork was carried out between 20 January and 2 February 1992 (MC and CS). Although the weather was generally unpleasant, we do not believe that collection efficiency was reduced. Fauna was collected from 30 sites.

Selection of streams

Four streams were selected by walking the area; the location of collection sites (fig. 1) was determined from the Tasmania 1:25 000 topographic sheet *Cathedral* (4236, Edition 2 1988), to which all grid references refer, using an altimeter and aerial photographs obtained from the 1976 Cradle Mountain Lake St Clair Project F505, Numbers T695-42 to T695-45.

Physical data

At each site elevation, slope and aspect were estimated using an altimeter, a compass and a clinometer. Water pH and temperature were measured using a Hanna Instruments® Portable Microprocessor pH Meter HI 8424. Water conductivity was determined using a Hanna Instruments® Portable Conductivity Meter HI 8633. Vegetation notes were made and summarised as communities (*sensu* Balmer 1991), with the most common species observed and identifiable being listed.

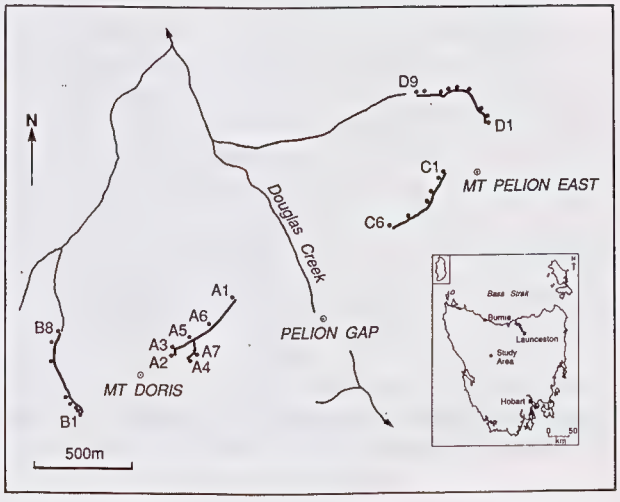

FIG. 1 — Location of study sites.

Sampling

Freshwater invertebrates and substrate samples were collected using an FBA net and hand sieves. Sampling continued until the collectors were confident that further effort would be unproductive; samples from each site were transferred to the base camp (Pelion Valley Ranger's Hut), hand sorted twice, and any fauna present preserved in formalin for later identification in Hobart.

The study streams

All four streams surveyed form part of the headwaters of Douglas Creek, itself a tributary of the Forth River. They flow through Permian/Triassic sandstones and quartzites. The Jurassic dolerite caps of Mts Doris, Ossa and Pelion East have formed scree slopes and blockstreams, largely through glacial and periglacial processes. The streams originate in these blockstreams and then flow through channels that do not seem to be actively eroding. Rather, the amount of moss in the channels and the discontinuous surface flow suggests that the channels are being infilled. Consequently the term "stream" is used somewhat loosely, since the distinctions between stream proper, pool, runnel, surface run-off, and even small tarn, were often very indistinct. Summary data identifying each collection site are provided in table 1.

Stream A is the least discrete of the streams sampled; it originates as a soak flowing from the vegetated lower section of the blockstream on the northeastern side of Mt Doris. The highest discernible point is a small tarn (Site A2, GR 209 645.5) with no inflowing channel. Seven samples were obtained from a 250 m length, with a fall from 1270 m to 1200 m where the stream flows over a small cliffline and into the treeline. It is not continuous (site A4 is directly downslope from A2 but there is no connecting channel) and overland flow obviously is a frequent feature of this "stream".

Stream B begins in the scree on the saddle between Mts Doris and Ossa and flows north. The originating pool is at 1254 m elevation (GR 205 642.5), and eight samples were obtained, the lowest being within the treeline at 1170 m. Total length of this section was 300 m. This stream is continuous, although some small tributary seepages also contribute to the flow.

Stream C originates as several small tarns on a shelf below the blockstream on the west face of Mt Pelion East at 1352 m. It flows southwesterly until it disappears underground just above a cliffline (c.1200 m) which is above the treeline north of Pelion Gap. This stream has no obvious continuous channel below the treeline. Six samples were taken from 1352 m to 1240 m, over a length of 400 m. Site C2 is the tarn marked at GR 223 654.

Stream D emerges from the scree slope above the saddle on the north face of Mt Pelion East at 1355 m and flows northwest towards the saddle. From the saddle it flows in a westerly direction down through the treeline to Douglas Creek. Although site D1 (GR 225 657.5) is on quartzite, there is dolerite lower down the slope, as a result of mass movement. The lowest sample (D9) was taken just below the treeline at 1260 m, 300 m from D1.

Statistical analyses

Sites and species were classified by cluster analysis using the statistical package PATN (Belbin 1991). For sites, the Kulczynski dissimilarity coefficient was calculated from log transformed data. The robustness of this coefficient as a measure of ecological distance was established by Faith *et al.* (1987). The dissimilarity matrix created was converted into site groupings, using the unweighted pair group average (UPGMA) procedure of Sneath & Sokal (1973). Dissimilarity coefficients for the classification of species according to their shared occurrences were obtained by the TWO-STEP measure of Austin & Belbin (1982). Since this measure is sensitive to species abundances, standardisation was carried out by dividing all samples by the square root of the sum of squares of the species' abundance (Austin & Belbin 1982). Clustering was again achieved using the UPMGA procedure. A two-way site/species table was created from the dissimilarity coefficients in order to examine the relationships between site and faunal groupings. As a test of the conclusions reached by clustering, ordination of the site data was also carried out with PATN, using semi-strong hybrid multi-dimensional scaling (Minchin 1987).

RESULTS

Descriptive summaries of each site and the fauna collected are provided in tables 1 and 2 respectively.

The streams proved to be somewhat depauperate, with the 30 sites yielding a total of 37 taxa (table 2). Of these, 13 occurred only once, and a further seven were found on two occasions only. Relatively few taxa could be considered common, the most frequently collected species being a phreodrilid annelid (21 sites), *Neoniphargus* sp. (18 sites) and *Anaspides tasmaniae* (8 sites); in addition, chironomids and tipulids, which were not identified beyond Family, were found at 14 and 11 sites respectively. Numerically, the collections were dominated by *Neoniphargus* sp. (752 individuals — a collection dominated by site A6), phreodrilids (297), *Antipodeus* sp. (74), *Anaspides tasmaniae* (73), and chironomid larvae (40). Diversity was similar in streams A and B (20 & 21 taxa respectively), a little lower in stream D (15 taxa) and much lower in stream C (9 taxa only); although fewer sites were sampled along stream C, the absence of fauna is probably because this stream was the most exposed — most sites faced SSW.

Only four taxa, the phreodrilid, *Neoniphargus* sp., tipulids and chironomids were collected in all streams, although the ubiquitous presence of the crayfish, *Parastacoides tasmanicus tasmanicus*, was also indicated by the occurrence of its burrows.

Clustering of the sites identified five putative groups (fig. 2). One of these is very large, incorporating 21 collection sites, one consists of a single site only and may be an artefact of the analysis, two are made up of three sites and the final group is defined by two sites. These groups were examined for any consistency in physico-chemical characteristics (table 3).

Group I consisted of a large collection of high-altitude sites, mostly small pools on moderate slopes, that represent the surface origins of the four streams studied. No consistent aspect is presented, though most sites are reasonably sheltered

within low-growing alpine heath and are characterised by warm water with relatively high conductivity and slight to severe acidity. The group contains all stream C sites, all but one from stream A and all but two from stream D, but only two sites from stream B.

Group II was a single site with close faunistic similarities to Group I. Although most physico-chemical characteristics overlap with those exhibited by Group I, they are generally at the extreme of the range; the clearest differences are the easterly aspect and the low (for this study) altitude.

Group III comprised three pool sites on flat ground with a westerly aspect, identified as part of stream B. The pools were large and shallow (table 1) and the water was relatively warm, with almost neutral pH and high conductivity.

Group IV consisted of three adjacent running-water sites on a reasonably steep, westerly facing slope; they were part of stream B as it approached the treeline, and drained the pools of Group III. The water was cold with low conductivity and near neutral pH, and the surrounding vegetation was above 2 m in height (table 1).

The final grouping recognised by the analysis (Group V) consisted of two lotic sites, facing west, on stream D; although they were the lowest sites for this stream, located at the edge of the treeline, they were still the second highest of the site groups. The slope was steep, the surrounding vegetation was relatively tall (2–4 m), and the water was cold, with low conductivity and almost neutral pH.

Clustering of the fauna identified four faunal groups (fig. 3). These appear to make good biological sense and represent a "seepage/runnel fauna", a "large pool/tarn fauna" and "stream faunas", of which two were revealed (fig. 3). Both stream faunas contain typical stream-dwelling taxa and their separation is considered to be an artefact of the analysis. It arises because one of them (Group 3) was formed by five taxa, all of which occurred at site B7, with four of them occurring nowhere else (table 4). Group 1 was characterised by 17 taxa that were collected from slow-flowing runnels and seepage pools at high altitudes. Most species occurred in low numbers at a reasonably large number of sites (table 2); notable exceptions were the phreodrilid annelid and the amphipod *Neoniphargus* sp., both very numerous at some sites. Four of the taxa collected may form part of a high-altitude aquatic fauna. One of these, *Neoniphargus* sp., is a crustacean, the others are Trichoptera (*Notoperata maculata*, an unidentified genus from the Kokiriidae and *Plectrotarsus* sp.).

Six taxa found in the larger, open pools and tarns grouped together to form Group 2. Although six sites had representatives of this assemblage, most specimens were collected from just two sites: site A2, where all six taxa were found, and site D2, where three were collected.

Groups 3 and 4 comprised 14 taxa commonly collected from cold upland streams in Tasmania. Not surprisingly, since they provided the most clearly identifiable stream systems, stream B and the lowest sites on stream D, they provided most of the material collected.

The two-way site/species matrix created from the dissimilarity coefficients obtained during the clustering analyses is presented in table 4.

The five site groupings discussed above are also identifiable following the ordination of the data, adding further support to the conclusion that they represent valid habitat categories. Figure 4, which is a scatter plot of axes 1 and 2, illustrates the separation of the groupings. In figure 4, site group V is overlaid by group III; these two groups are clearly separated by axis 3.

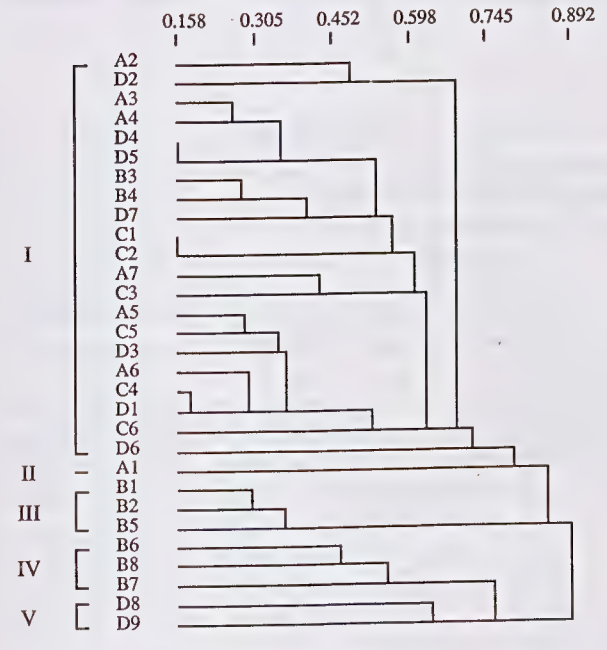

FIG. 2 — Dendrogram resulting from cluster analysis of sites (see table 1) by taxa. The horizontal scale is dissimilarity measured by the Kulczynski coefficient.

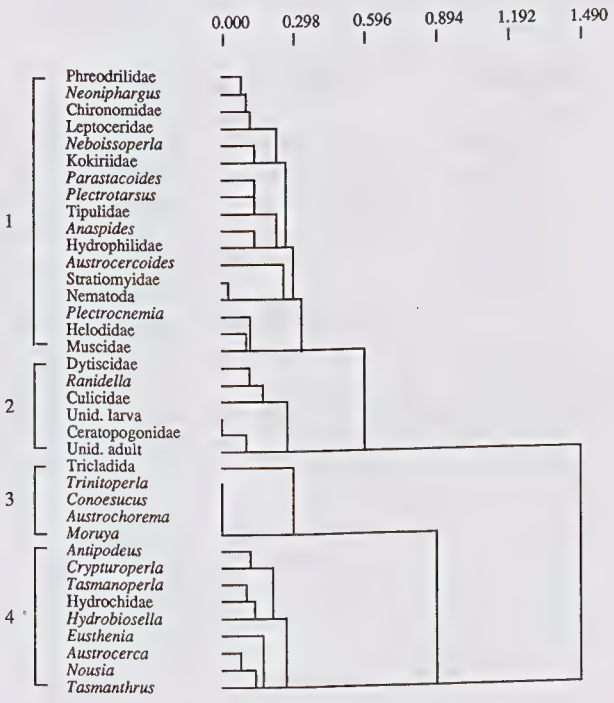

FIG. 3 — Dendrogram resulting from cluster analysis of taxa by occurrence. The horizontal axis is dissimilarity measured by TWO-STEP (Austin & Belbin 1982).

TABLE 1
Summary of site descriptions

Site	Elev. m	Aspect	Slope °	Temp °C	pH	Cond. µS/cm	Substrate	Description	Dimensions L×W×D m	Vegetation Community
Stream A (NE from Mt Doris)										
A2	1270	NNE	5	10	3.84	16	Mud	Tarn	3×5×0.1	Coniferous heath (3m,shrubbery)
A3	1270	NNE	5	9.6	5.58	26	Moss	Stream 5m below A2	5×0.3×0.02	Coniferous heath (3m,shrubbery)
A4	1245	ENE	2	10.9	4.51	27	Mud/moss	Two connected pools 30m below, but separated from A2	1.4×1×0.2; 0.7×1.3×0.15	Conif heath(1.5m)
A7	1240	N	2	9.7	4.35	41	Mud	Two pools near break in slope between A4 &A5	3×2×0.15; 2×1×0.2	Conif. heath/short alpine herbfield
A5	1240	NE	<2	12.2	4.35	22	Mud/moss	String of pools 60m from A4	5×0.3×0.2	Alpine heath (1m)
A6	1210	NNE	5	9.2	4.17	32	Moss,rock	String of pools in heath, no channel	5×0.6×0.2	Alpine heath (0.5m)
A1	1200	ENE	10	9.3	4.22	31	Mud, moss	Pools and fen at edge of cliffline	0.3×0.3×0.2	Alpine heath (0.5m)
Stream B (N from Ossa/Doris saddle)										
B1	1254	NW	<2	12.6	6.07	34	Mud	Pool in dolerite boulders	3×3×0.8	Bolster heath
B2	1254	NNW	<2	14.3	6.38	27	Mud	Pool 10m from B1 connected by fen	3×3.5×0.3	Bolster heath
B3	1252	NW	5	8.7	5.64	29	Moss	Pool 30m from B2	1.5×1×0.3	Alpine heath (1m)
B4	1245	WNW	2	12	5.88	18	Mud/moss	Stream 20m from B3	5×0.2×0.05	Alpine heath/short alpine herbfield
B5	1245	NW	2	7.1	6.14	23	Mud/moss	Stream with pools 10m from B4	5×0.1×0.1	Alpine heath
B6	1215	WNW	7	6.8	6.4	13	Moss	Stream flowing under pencil pines 25m from B5	5x0.1x0.1	Coniferous heath (2m, Shrubbery) coniferous alpine
B7	1190	NNW	10	7.3	6.23	17	Rock, litter	Stream flowing over rock at edge of treeline, 100m from B6	5×0.4×0.1	Alpine heath(2m)
B8	1170	NNW	30	8.7	5.72	16	Gravel, litter	Stream 100m from B7	5×0.6×0.2	Alpine woodland (3m)
Stream C (SW from tarns on W face of Pelion East)										
C1	1352	SSW	<2	23.8	5.24	20	Mud,moss, plants	Tarn at foot of dolerite block stream with no incoming channel	8×6.5×0.3	Alpine heath (0.5m)
C2	1350	SSW	<2	16.8	5.19	21	Rocks,mud	Large tarn on shelf fed from C1 via a series of small pools, 30m from C1	15×15×0.5	Alpine heath (1m)
C3	1348	SSW	5	18.7	4.84	18	Mud,moss, plants	Pool 25m from C2 fed by soaks and pools	5×3×0.1	Alpine heath (0.3m)
C4	1335	SSW	20	9.7	5.62	18	Mud	3 main pools 100m from C3 fed by soaks and small channels in a semi-buried blockstream	1.5×1.5×0.1; 0.5×0.4×0.15; 1.5x2×0.1	Alpine heath(0.3m)/ bolster heath
C5	1280	SW	15	7.8	5.65	10	Mud	Stream 120m from C4	5×0.4×0.1	Bolster field/fen
C6	1240	WSW	20	9.8	5.65	13	Mud	Pool and stream fed by soaks and fen disappearing underground	0.3×0.5×0.4(p) 3×1×0.15(st)	Alpine heath(1m)

Table 1 cont.

Site	Elev. m	Aspect	Slope °	Temp °C	pH	Cond. µS/cm	Substrate	Description	Dimensions L×W×D m	Vegetation Community
Stream D (W from saddle N of Pelion East)										
D1	1355	NW	10	11.9	6.29	22	Moss	Pools linked to drainage heading towards saddle	3.5×0.2×0.2	Bolster heath/ alpine heath (0.3m)
D2	1350	WNW	7	17.2	5.98	20	Mud	Pool 40m from D1	4×3×0.2	Alpine heath(0.3m)/ bolster heath
D3	1345	W	5	14.3	5.36	22	Moss	Pools 25m below D2	5×0.2×0.15	Alpine heath(0.3m)/ bolster heath
D4	1335	W	5	19.7	5.32	22	Moss	Pools 30m from D3 around cushion plants with identifiable channel	5×0.2×0.1	Alpine heath(0.3m)/ bolster heath
D5	1325	WSW	15	9.5	5.35	18	Moss	Infilled channel with soaks and pools, emerges from fen above, 50m from D4	5x2x0.1	Alpine heath(0.3m)/ bolster heath
D6	1320	WSW	20	11.1	5.96	24	Moss	Stream 20m from D5	5×0.2×0.1	Bolster heath
D7	1310	W	12	10.3	6.42	20	Moss	Stream 30m from D6	5×0.15× 0.01-0.1	Bolster heath/alpine sedgeland(0.01m)
D8	1280	W	20	7.2	6.13	16	Moss	Stream 100m from D7, just above treeline	5×0.2× 0.01-0.1	Alpine heath(2m, shrubbery)
D9	1260	SW	35	8.3	6.72	15	Gravel/sand/ mud/litter	Stream within treeline, 100m from D8	5×0.5×0.2	Wet forest(4m)

DISCUSSION

The 37 taxa collected represent about half the number recorded from lower altitude streams and rivers in western and south-western Tasmania (Swain & White 1985). The restricted fauna collected is presumably directly related to the two dominant characteristics of the "streams" sampled: lack of protection from climatic extremes and the absence of a distinct stream course. The "streams" were essentially collection pools of varying size connected, often only tenuously, by seepage channels. It is usually not until the drainage course reaches the protection of the treeline that a distinct stream channel can be identified.

Our original intention was to sample into the treeline. This proved impossible in streams A and C, and difficult in B and D, where single samples, 100 m below the treeline, were obtained in each case. Consequently, it is not possible to compare above and below faunas in any detail. It would be expected that both diversity and abundance would increase below the treeline, but the present survey provides no strong support for this hypothesis. However, it is worth noting that in stream B, at least, both taxa and individuals were most abundant at and below the treeline (table 2). Indirect support also comes from Dean & Cartwright (1992) who, working at lower altitudes in the same area, found far fewer plecopteran, ephemeropteran and trichopteran species in small headwater streams than in larger downstream sites.

Several taxa were recorded from above the treeline only, and four of these justify further investigation as potential representatives of a specialised high-altitude fauna. These are *Neoniphargus* sp. (Amphipoda) and the trichopterans *Notoperata maculata*, the unidentified genus from the Kokiriidae and *Plectrotarsus* sp. No firm conclusions can be reached until the streams have been surveyed at lower altitude, but it is interesting that none of the Trichoptera were recorded by Dean & Cartwright (1992) in their survey of aquatic insects from forested sites in the Pelion Valley. Although there may be a small number of species exclusively associated with habitats above the treeline, it would appear from our preliminary survey that the high-altitude aquatic fauna is characterised by the loss, rather than the appearance of species. Thus, for example, the greatest numbers of Plecoptera and Ephemeroptera were collected at or below the treeline, and both taxa were absent from the highest sites on each "stream" (table 2); the highest altitude for stoneflies was 1280 m (C5, D8), whilst mayflies were much scarcer, occurring at three sites only, the highest of which (D9 — 1260 m) was below the treeline. Most of the stonefly and mayfly nymphs collected were recently hatched, so it is possible that their apparent absence from the higher sites reflects adult requirements for oviposition rather than nymphal habitat needs. However, most species possess two-year life cycles, and the scarcity of larger nymphs in the collections suggests that habitat unsuitability is the more reasonable explanation.

Generalisations, however, are complicated by the very loose definition of "stream" that has been employed. The origins of high-altitude streams are generally indistinct and, although continuity between pools and seepages can usually be determined, a clear stream course is not usually established until below the treeline. In each of the "streams" examined in the present study, the fewest taxa were invariably found in small pools and soaks in very shallow soils (A1, A7, B1, B2, B3, B5, C1, C3, D1); most of these pools were filled by surface collection of rainwater rather than by seepage through the soil. Even though these pools were sampled during a period of persistent rain, only one (B1) was deeper than 30 mm. Few species are able to withstand the harsh and unpredictable conditions presented by such habitats.

TABLE 2
Fauna collected at each site

Taxon	Code*	A2	A3	A4	A7	A5	A6	A1	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	D9	Totals
Oligochaeta																																
'Phreodrilidae'	a	2	26	8	1	4	15				5	13				80	60	1	15	5		21	8	1	7	9	1	10		5		297
Turbellaria																																
Tricladida	x					1									1																	2
Crustacea																																
Amphipoda																																
Neoniphargus sp.	b	1	1			30	500	5	1	1			2						54	28	39	49	1	29	1	1	2	6	1		752
Antipodeus sp.	C													3	7	10													44	10	74
Decapoda																																
Parastacoides t. tasmanicus	g		p†	p				p				p			1					p	1		p								2
Syncarida																																
Anaspides tasmaniae	j								12	35	2	3	8	1		1												11			73
Insecta																																
Plecoptera																																
Eustheniidae																																
Eusthenia spectabilis gp	H															2														3	5
Notonemouridae																																
Austrocerca tasmanica	I															10															10
Austrocercoides sp.	I																													1	1
Gripopterygidae																																
Neboissoperla sp.	e					1															1	2									4
Trinotoperla tasmanica	y														1																1
Austroperlidae																																
Crypturoperla paradoxa	D												2	3	20	2															27
Tasmanoperla thalia	E													1	1	7															9
Ephemeroptera																																
Leptophlebiidae																																
Nousia sp. 7	J													1		12															13
Trichoptera																																
Leptoceridae																																
Notoperata maculata	d	1			3	5	20	2																								31
Plectrotarsidae																																
Plectrotarsus sp.	h		1	1		1																		1	2		1					7
Philorheithridae																																
Tasmanthrus galbinomaculatus	K													1		1																2
Kokiriidae																																
unidentified genus	f																					10										10
Conoesucidae																																
Conoesucus sp.	z															1																1
Polycentropodidae																																
Plectrocnemia sp.	o			1																												1
Philopotamidae																																
Hydrobiosella cognata?	G															2	1															3
Hydrobiosidae																																
Austrochorema sp.	A															1																1
Moruya sp.	B															1																1
Coleoptera																																
?Hydrochidae sp.	F	1							3						1	2	4															11
Dytiscidae sp.	r	1						1											1					3						1	7
unidentified larva	u	1																														1
unidentified adult	w	2																														2
?Hydrophilidae sp.	k			4						1			1		1																	7
Helodidae sp.	P			1																												1
Diptera																																
Tipulidae sp.	i			3	3	5	2	1					1			1			1		1				1	1						20
Culicidae sp.	t	3														1								1								5
Chironomidae sp.	c	4	2	1		1	1				2								6	1					5	3	3	7	1	3		40
Cerotopogonidae sp.	v	1																														1
Muscidae sp.	q		1	1														1														3
Stratiomyidae sp.	m																											2	1			3
Nematoda																																
sp.	n																											3				3
Amphibia																																
Ranidella tasmaniensis	s	6																						13								19
Totals		23	39	15	9	45	538	10	14	38	7	18	12	12	38	52	80	62	1	76	35	53	70	27	38	12	14	16	29	48	20	1450

* Cross reference code for table 4. † Burrows present

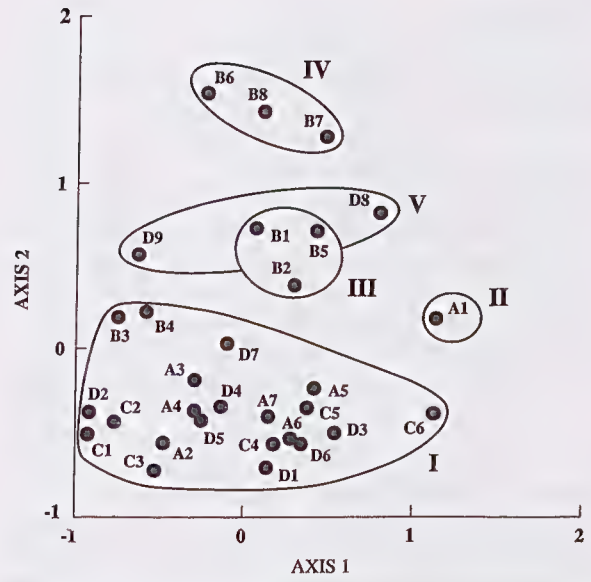

FIG. 4 — Grouping of study sites along ordination axes 1 and 2 following semi-strong hybrid multidimensional scaling. Roman numerals identify the site groupings identified in figure 2.

Syncarids, amphipods and stoneflies were expected to be of interest because they appeared to offer the best potential for delimiting high-altitude aquatic faunas. The two crustacean groups are fully aquatic and, therefore, should appear in collections made at any time of year. The stoneflies are the best known of the Tasmanian aquatic insect fauna and contain numerous low temperature adapted species (Hynes & Hynes 1980). Seven species, representing all four Tasmanian families, were collected in this study, but distributions were very patchy. For example, no species was found in more than two streams, and four occurred in only a single stream; furthermore, within any particular stream, distribution was always very localised. The single specimen from site A5, a newly hatched nymph identified as *Neboissoperla* sp., was the only stonefly species not recorded also by Dean & Cartwright (1992).

The distribution of *Anaspides tasmaniae* does not appear to be of special interest. The absence of the species from streams A and C may be explained by the presence of a physical barrier, since both these streams disappear over cliffs before entering the treeline (table 1). The occurrence at only one site on stream D may be altitude dependent, since that site is higher than any of the sites on stream B; however, *A. tasmaniae* are highly mobile and, since the animals caught were all adult, it is likely that further collecting would demonstrate their presence in at least some of the higher sites on this stream.

TABLE 3
Summaries of physico-chemical data relating to the five site groupings*

(A) Quantitative summary – means (±s.e.)

Group	No of sites	Slope °	Temp °C	pH	Conductivity µS cm^{-1}	Elevation m	Aspect °
I	21	8.9	12.5	5.3	21.9	1296	206.7
		(1.40)	(0.93)	(0.15)	(1.46)	(10.7)	(23.22)
II	1	10.0	9.3	4.2	31.0	1200	67.5
		(–)	(–)	(–)	(–)	(–)	(–)
III	3	2.0	11.3	6.2	28.0	1251	322.5
		(0.00)	(1.77)	(0.08)	(2.62)	(2.4)	(6.12)
IV	3	15.7	7.6	6.1	15.3	1191	322.5
		(5.89)	(0.46)	(0.17)	(0.98)	(10.6)	(12.25)
V	2	27.5	7.8	6.4	15.5	1270	247.5
		(5.30)	(0.39)	(0.21)	(0.35)	(7.1)	(15.91)

(B) Qualitative summary

Group	Cover height	Slope	Temp	pH	Conductivity	Elevation	Aspect
I	low	moderate	warm	acid	high	high	varied
II	low	moderate	warm	acid	high	low	northeast
III	medium	flat	warm	neutral	high	moderate	northwest
IV	"tall"	steep	cold	neutral	low	low	northwest
V	"tall"	steep	cold	neutral	low	high	westerly

* Identified by cluster analysis

TABLE 4
Two-way table of site-taxa groupings

Site group/ site	Faunal group*																																						
	1																			2						3						4									
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	A	B	C	D	E	F	G	H	I	J	K			
I/ A2	1	1	4	1														1	5	5	5	5																		
I/ D2	3	1					5	1										5	5	1																			
I/ A3	4	1	2				5	1	4		5					5	5																						
I/ A4	3		1				5	1	4						5		5																						
I/ D4	2	1	3						1																														
I/ D5	3	1	3					1																														
I/ B3	2									2																												
I/ B4	3						5		1	2	1																												
I/ D7	3	2	1							3			1																										
I/ C1	5																																						
I/ C2	5																5	1																					
I/ A7	1			2					5																														
I/ C3	1																																						
I/ A5	2	3	1	3	1			1	2															5															
I/ C5	2	3	1		1		5																																
I/ D3	1	3	4					5	1																														
I/ A6	3	5	1	5					1									1																					
I/ C4	3	3	5						1																														
I/ D1	4	3																																					
I/ C6		3			5	5	5		1																														
I/ D6	1	1	5										5	5																									
II/ A1		2		2			5																								4								
III/B1		1								4	1																												
III/B2		1	2							5																													
III/B5		1								3																			1										
IV/B6										1	1																		1	2	1	1				1		5	
IV/B8									1	1										1									3	1	5	5	1	1	5	5		5	
IV/B7							5																	5	5	5	5	5	2	5	1	3	5						
V/ D8		1	3																										5										
V/ D9	2											5						1											3					5					

* see table 2 for taxa identifications

Neoniphargus sp. was found in the full range of habitats investigated, except at those sites located below the treeline (B8, D9), suggesting that the species may be restricted to high altitudes. In contrast, *Antipodeus* sp. was collected only from sites immediately above or within the treeline (B6, B7, B8, D8, D9). It was never found in any of the "pool" habitats and was absent from streams A and C, presumably because the cliffs prevented penetration from downstream, forested sites. Distribution of the two amphipod species appeared to be mutually exclusive, and only at D8, where a single *Neoniphargus* sp. specimen was present among 44 *Antipodeus* sp., was co-occurrence recorded.

The analysis of the physico-chemical characteristics of the site groupings suggests that, with the possible exception of group II, the five groups identified in figure 2 form a reasonably coherent set of sites. Their validity is supported by the ordination of the data (fig. 4). Table 4 enables the faunal bases of these groups to be examined and conclusions to be drawn about their biological validity.

The large number of sites in Group I might suggest that this is something of an eclectic group. However, it is clearly well defined faunistically (table 4) and is created almost entirely by its faunal group 1 component. We conclude, therefore, that the high-altitude runnels, seepages and soak pools, from which identifiable streams develop, do form a coherent set of biological habitats with its own distinctive, though not exclusive, fauna.

Group II is not well defined faunistically; this single site grouping is separated from Group I by the relatively high abundance of one of the taxa from faunal Group 4

(?Hydrochidae sp.). This suggests that site A1 (Group II) is unlikely to represent a distinct habitat category. However, the site did possess a unique combination of physico-chemical characteristics (table 3) and it would perhaps be wise to search for other sites with these features before making a final decision on the validity of this group.

Site Group III is characterised by stream-dwelling taxa from faunal groups 1 and 4, suggesting that high-altitude flowing water sites represent an identifiable habitat utilised mostly by a subset of high-altitude seepage/runnel species, but also penetrated by a small number of additional stream species such as the stonefly *Crypturoperla paradoxica.*

Site Group IV is more certainly a distinct habitat type, defined unequivocally by faunal groups 3 and 4. It represents "typical" stream habitats immediately below the zone of origin at or very close to the treeline.

Group V is distinguished by its fauna much less clearly than by its physico-chemical characteristics. It contains elements of both faunal groups 1 and 4, possibly because it shares physico-chemical properties with both site groups I and IV.

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(accepted 17 November 1993)

MARINE NEOGENE SAMPLES FROM AROUND TASMANIA: AN EXTENSION TO THE MIOCENE/PLIOCENE MARINE RECORD IN TASMANIA

by Patrick G. Quilty and Andrew Telfer

(with two tables, three text-figures and two plates)

QUILTY, P.G. & TELFER, A., 1994 (30:vi): Marine Neogene Samples from around Tasmania: an extension to the Miocene/Pliocene marine record in Tasmania. *Pap. Proc. R. Soc. Tasm.* 128: 41–56. ISSN 0080–4703. Australian Antarctic Division, Channel Highway, Kingston, Tasmania, Australia 7050 (PGQ); Engineering and Water Supply Department, Box 603, Mount Gambier, South Australia, Australia 5290 (AT).

New Miocene and Quaternary foraminiferid faunas have been recovered from previously unrecorded localities onshore near Penguin and Strahan, and at nine offshore localities off northwestern, northeastern and southeastern Tasmania. Most Miocene benthic forms found in these samples are well known from other Tasmanian Tertiary sections but a few previously unreported taxa are recorded in Tasmania for the first time. Two samples from off northeastern Tasmania are Miocene. The sample from southeastern Tasmania is Early Miocene with Quaternary overlying it. Pebbles from Ocean Beach, north of Strahan, contain earliest Middle Miocene faunas. Other samples from off northeastern and northwestern Tasmania contain Quaternary faunas which probably reflect both periods of lower sea level and cool water and also periods of higher sea level and warmer water.

These samples extend the range of Miocene calcareous sediments much farther south on both west and east coasts of Tasmania. They also reinforce the pattern of Tasmanian Neogene sedimentation cycles (earliest Early Miocene, latest Early–earliest Middle Miocene, mid-Late Pliocene) identified previously.

Key Words:Neogene, Miocene, Quaternary, marine fauna, Tasmania, foraminifera.

INTRODUCTION

The biostratigraphy of Tasmanian Tertiary marine sediments was summarised by Quilty (1972), and the foraminiferid faunas were documented by Quilty (1974, 1977a, 1980a, 1982). Since then, fieldwork on Flinders Island, and accidental sediment recoveries during trawling by Tasmanian Sea Fisheries (then the Tasmanian Fisheries Development Authority, TFDA) have yielded foraminiferid bearing samples (Quilty 1985a, b). Further biostratigraphic data have been obtained from drilling for hydrocarbons. The most recent biostratigraphic summary that includes references to the Neogene is the relevant section of Burrett & Martin (1989).

The aim of this paper is to record the foraminiferid faunas and interpret the environment of deposition of several new Tasmanian Neogene samples. A revised model of the Tasmanian marine environment during the Neogene will then be presented.

Unfortunately, conditions throughout the Miocene–Quaternary in the waters around Tasmania generally were cool enough, with exceptions noted by Quilty (1972), that low-latitude, planktonic foraminiferid-based zonations such as those of Blow (1969) and Stainforth *et al.* (1975) are not readily applicable, and it is necessary to use both southeastern Australian benthic zonations, such as proposed by Carter (1958, 1964), Ludbrook & Lindsay (1969), and also mid-latitude, planktonic foraminiferid-based schemes such as those of Jenkins (1971, 1985) and Kennett & Srinivasan (1983). These schemes do not provide the resolution of zones, as do the Blow/Stainforth schemes mentioned above, nor do they allow spot samples, such as available here, to be dated with the precision of samples from warmer water continuous sequences. Another feature is that some samples were deposited in waters shallow enough for the full diversity of planktonic foraminiferids in existence in the region not to be represented in the sediments.

Samples and location

Locations of the samples are shown in figure 1. Detailed coordinates, depth and University of Tasmania acquisition numbers are shown on table 1.

The sample from between Penguin and Ulverstone (UTGD76649, near sea level, below the Lonah Road, between Tea Tree Point and Penguin Point; fig. 2) was discovered late in 1986 by the Tasmanian Geological Survey (now Mineral Resources, Tasmania), during fieldwork related to the large landslip known as Grooms Slip. The features of the slip were reported initially by Balsille (1936). A very thin, fossiliferous horizon is present and consists of sandy, silty clay with approximately 30% shell material in small lenses. It comes from the base of the cliff section next to an adit located above the centre of the slip and on a level at, or slightly above, a wave cut bench. Sediments above the marine horizon appear to be nonmarine clayey sand and sand.

Several offshore samples (UTGD66532–536) were recovered by CSIRO in 1986, as an unexpected and unwanted benefit of trawling activities during fishery research cruises in the region, conducted on R/V *Soela* (Cruises SO3/86 and SO4/86). In mid-July 1992, one was collected accidentally in approximately 1000 m water depth from an area known locally as the St Helens Hills during fishing operations of FRV *Southern Surveyor* (Cruise SS3/92). The St Helens Hills is the local term applied to an area of water depth 580–1000 m lying about 45 nautical miles east of St Helens, a known Orange Roughy (*Hoplostethus atlanticus* Collett) fishing area with a rugged bottom.

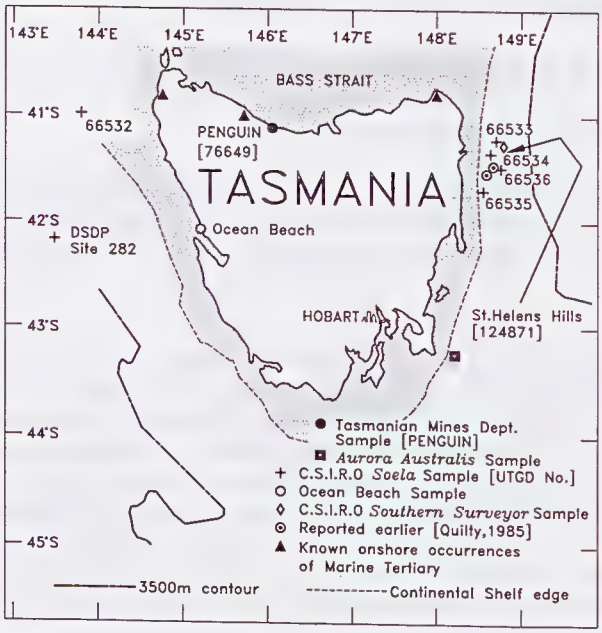

FIG. 1 — Locality map.

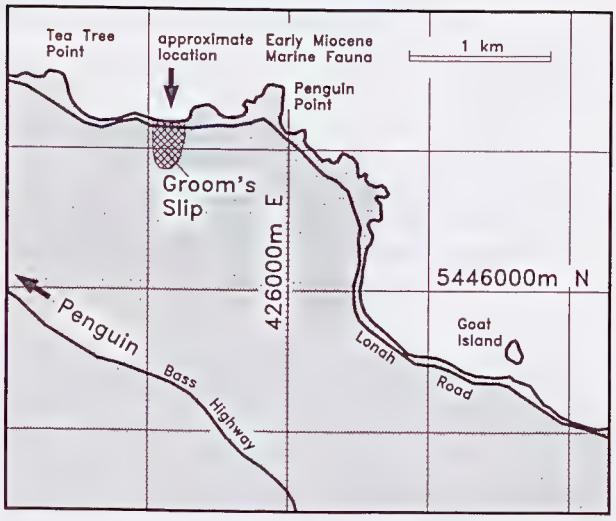

FIG. 2 — Details of location of Grooms Slip sample.

TABLE 1
Sample information

Location	UTGD sample	Latitude	Longitude	Depth (m)
Soela *samples*				
Western Tasmania				
S03/86 Station 31	66532	41°01'S	143°51'E	560
Eastern Tasmania				
S04/86 Station 3	66535	41°42'S	148°43'E	1160
S04/86 Station 5	66536	41°38'S	148°50'E	940
S04/86 Station 7	66533	41°15.7'S	148°46.9'E	1136
S04/86 Station 8	66534	41°26'S	148°44.8'E	870
St Helens Hills	124871	41°14'S	148°45.5'E	c.1000
Ocean Beach, Strahan	124886	42°07.5'S	145°15.5E'	0
	124887			
	124888			
	124889			
	124890			
	124891			
Aurora Australis *sample*				
Southeastern Tasmania	78185	43°15.53'S	148°14.25'E	810
North Coast, Penguin outcrop	76649	41°37.2'S	146°6.4'E	0

Samples collected from off northeastern Tasmania by CSIRO are from within a few nautical miles of the samples reported by Quilty (1985b).

The core from offshore southeastern Tasmania was taken on 3 January 1993, during testing of gravity coring equipment supplied by the Australian Geological Survey Organisation (AGSO), from RSV *Aurora Australis* under charter to the Australian Antarctic Division. The core is approximately 200 mm long, and has a diameter of 85 mm. There is some poorly controlled bottom profiler information for this site.

The samples from Ocean Beach, 6 km north of Strahan, consist of six rounded beach pebbles, 40–60 mm in diameter, in which mollusc fossils are abundant and clearly visible. They were collected early in 1993. Their source is not known but is likely to be nearby, probably offshore in waters less than 30 m deep. They probably have been brought to the beach by wave activity. They are much softer and less smoothed and rounded than other abundant beach pebbles of tough, silica rich Palaeozoic and Precambrian rocks, which seem to be brought to their position by longshore currents or reworked onto the beach from pebble horizons in nearby Quaternary sediments. The older material is probably redistributed from conglomerates in the Palaeogene and Quaternary sediments that fill the Macquarie Harbour Graben (Baillie & Corbett 1985). The Neogene calcareous pebbles are taken to be within a few kilometres of their source.

Processing

Material from most samples was soaked in water or Calgon solution to disaggregate. It was then washed over sieves, and the residue retained on sieves coarser than 125 microns was picked to yield the faunas recorded here. The sample from the *Aurora Australis* core was more indurated than the others, and some crushing was needed before routine processing. The samples from Ocean Beach, Strahan, and from the St Helens Hills were studied from thin sections, as they were too indurated for disaggregation.

Sample repository

Specimens of the rocks yielding the faunas are held in the collections of the Geology Department, University of Tasmania. Table 1 shows the relationship between the number of that specimen in the Geology Department collection and field numbers. Mounted foraminiferid specimens from each sample are held by the senior author. Figured specimens of foraminiferids are housed in the UTGD collections, and accession numbers for the figured specimens are given on the plate explanation. Geology Department (UTGD) numbers are used throughout this paper.

FAUNAS, AGE AND PALAEOECOLOGY

Penguin–Grooms Slip

Lithology

UTGD76649 is soft, friable, apparently nonbedded, poorly sorted, iron-stained, shelly marl that disaggregates readily.

Age

The diverse foraminiferid fauna from the single sample is very similar to that reported by Quilty (1972) from the lowest part of the Fossil Bluff section, 37 km to the northwest. Both sections occur within a few metres of modern sea level. Approximately 99% of the fauna is of benthic species, which are dominated by "*Valvulineria*" *kalimnensis* (Parr), *Elphidium* spp. and several miliolid species, including *Crenulostomina banksi* Quilty. The species distribution is shown on table 2. *Sherbornina cuneimarginata* and *Globorosalina scabricula* (Chapman) are recorded for the first time in Tasmania. Planktonic species are uncommon, and only *Globigerina brazieri* Jenkins and *G. connecta* Jenkins have been identified from the sample. Other elements of the biota include wood fragments, bryozoans, cirripedes, gastropods, bivalves and rare fish otoliths.

Key benthic species for age determination in the Carter (1958) Faunal Unit scheme are *Calcarina mackayi* (Karrer), *Planorbulinella inaequilateralis* (Heron-Allen and Earland), *Sherbornina cuneimarginata*, *Notorotalia howchini* (Chapman, Parr and Collins) and *Operculina victoriensis* Chapman and Parr. *P. inaequilateralis*, although stated by Carter to appear in Faunal Unit 7, has been documented by Quilty (1982) from Faunal Unit 6 sediments at Fossil Bluff, Wynyard, where "*Valvulineria*" *kalimnensis* also is abundant and commonly the dominant species.

The fauna is typical of assemblages that can be correlated with Carter's (1958) Faunal Unit 6, which is earliest Miocene (approximately N5, *Globoquadrina dehiscens praedehiscens–G. dehiscens dehiscens* Partial-range zone of Blow 1969: see figure 3, based on Abele, in Douglas & Ferguson 1976).

Palaeoenvironment

Dominance (the proportion of the benthic fauna made up by the dominant species – Walton 1964, Quilty 1972) is 17%, and Diversity (the number of species making up 95% of the benthic fauna) is 18. These figures are characteristic of faunas from the deeper end of the 0–10 fathom field identified by Quilty (1972). Other elements of the biota noted above, however, suggest shallower water deposition and are a little at variance with the Dominance/Diversity figures. Dominance is lower and Diversity higher than expected from interpretation based on other elements of the fauna. The evidence from planktonic percentage and macrofauna is consistent with deposition in a close inshore, protected environment within a few metres of sea level.

TABLE 2
Distribution of foraminifera in the samples

Benthic species	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Acervulina inhaerens							X							
Alabamina tenuimarginata														
Ammobaculites sp.			X		X									
Amphicoryna hirsuta			X											
Annulopatellina annularis														X
Anomalina globulosa			X											
Anomalinoides macraglabra													X	
A. nonionoides	X		X											
Astrononion australe														X
A. centroplax													X	
A. stelligerum				X										
Bolivinella elegans														X
Buliminella elegantissima														X
B. sp.													X	
Calcarina mackayi														X
Carpenteria rotaliformis							X						X	
C. cf *rotaliformis*														
Cassidulina laevigata													X	
C. neocarinata													X	
Chilostomella oolina			X											
C. sp.														
Cibicidella variabilis				X										
Cibicides cf *cicatricosus*			X											
C. lobatulus	X			X										
C. mediocris					X									
C. notocenicus	X													
C. perforatus					X	X							X	
C. cf. *perforatus*									X	X	X			
C. pseudoungerianus				X										
C. refulgens									X					
C. subhaidingeri	X													
C. thiara													X	
C. sp.														X
Crenulostomina banksi														X
Cribrononion poeyanum)														X
Dentalina cf *subemaciata*	X													
D. filiformis		X												
D. sp	X													X
D. subsoluta	X	X												
Discorbinella bertheloti			X											
D. subbertheloti			X											
Discorbis balcombensis				X	X									
Dorothia parri				X									X	
Ehrenbergina sp.		X												
Elphidium chapmani														X
E. crassatum														X
E. crespinae					X		X						X	
E. grimensis														X
E. parri														X
E. spp. indet.							X	X						
Epistomina elegans	X		X											
Eponides repandus					X								X	
E. tenera		X												
'Eponides' (*Cibicides*) *bradyi*	X													
Euuvigerina compacta							X							
Fissurina spp.		X												
Florilus victoriensis														X
Gaudryina convexa					X								X	
Gavelinella sp.									X					
Gavelinopsis sp	X													
Gen. cf. *Carpenteria*										X				
gen. et sp. indet.					X									
Globobulimina turgida			X											
Globocassidulina subglobosa								X	X				X	X
Globorosalina scabricula														X
Guttulina communis					X									
G. problema					X								X	
Gypsina globulus					X		X	X						
Gyroidina allani													X	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Heronallenia lingulata					X									
H. parri														X
Karreria maoria					X					X				
Karreriella novangliae		X												
Lagena laevis		X												
Laticarinina halophora		X												
Lenticulina sp.1	X													
Lenticulina sp.2	X													
Lenticulina sp.3	X													
Lenticulina sp.					X									X
Marginulina spp.														X
miliolids indet.								X						
Miliolinella subrotunda			X											X
Notorotalia howchini														X X
N. sp.						X								
Oolina globosa		X			X									
Operculina victoriensis					X									X
O. sp.)					X									
Pileolina sp.														X
Planodiscorbis irregularis					X									
Planorbulina cf. *mediterranensis*						X								
Planorbulinella inaequilateralis														X
Planulina cf. *ariminensis*					X									
P. wuellerstorfi			X											
Planulinoides biconcavus														X
Pseudoclavulina cf. *anglica*				X										
Pullenia bulloides		X	X											X
P. quinqueloba														X
Pyrgo elongata			X											
P. sp.						X								
Quinqueloculina angularis			X											X
Q. aspera														X
Q. cuvieriana			X											
Q. laevigata			X											
Q. cf. *lamarckiana*								X						
Q. sp.			X			X	X							
Reussella simplex					X									
Sherbornina cuneimarginata														X
S. sp.								X						
Sigmoilopsis schlumbergi														
Sigmomorphina sp.					X									
Siphonina australis														X
Sphaeroidina bulloides		X			X									
Spirillina tuberculata			X											
S. sp.					X									
Stilostomella abyssorum	X													
S. sp.						X								
Stomatorbina concentrica					X									X
Svratkina australiensis														X
Textularia gramen						X								X
T. cf *hayi*			X											
T. sp.						X	X		X	X	X			
Triloculina affinis														X
T. laevigata														X
T. trigonula			X											
T. sp.														X
Vaginulinopsis albatrossi	X													
Valvulineria kalimnensis														X
Vulvulina pennatula	X													
Planktonic species														
Globigerina angustiumbilicata							X		X	X				
G. bulloides	X	X	X										X	
G. cf. *bulloides*							X							
G. concinna		X	X											
G. connecta				X										X

Table 2 cont.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
G. falconensis	X	X												
G. foliata			X	X										
G. internec *woodi-brazieri*	X													
G. venezuelana						X								
G. woodi				X				X		X	X			
G. cf *woodi*					X	X								
G. sp.			X			X		X					X	
Globigerinita incrusta				X										
G. sp.	X	X		X						X	X			
Globigerinoides obliquus obliquus	X													
G. quadrilobatus					X									
G. quadrilobatus immaturus	X					X								
G. quadrilobatus quadrilobatus	X													
G. quadrilobatus sacculifer	X													
G. quadrilobatus trilobus	X													
G. sp.							X	X						
G. extremus		X												
Globoquadrina dehiscens dehiscens				X		X				X				
G. altispira					X	X								
G. sp.						X					X			
Globorotalia cf. *conomiozea*			X							X	X			
G. cf. *conoidea*						X				X	X			
G. cf. *conoidea/miozea*											X			
G. crassaformis							X							
G. crassula							X							
G. inflata							X	X	X					
G. miozea							X						X	
G. cf. *miozea*							X			X				
G. nana														X
G scitula scitula							X	X		X	X		X	
G. cf. *scitula*									X					
G. tosaensis							X							
G. truncatulinoides							X	X	X					
G. cf. *tumida*								X		X				
Hastigerina pelagica								X						
Orbulina bilobata								X						
O. universa							X	X		X	X			
Praeorbulina glomerosa circularis									X					
P. glomerosa glomerosa											X			
P. glomerosa undiff.										X				
? Pulleniatina cf. *primalis*										X				
Sphaeroidinella sp.										X				
Sphaeroidinellopsis cf. *subdehiscens subdehiscens*										X				
Classification uncertain														
Triangulina aequilateralis														X

* Key to localities. (A–E) CSIRO samples, UTGD66532, UTGD66535, UTGD66536, UTGD66533 and UTGD66534 respectively; (F) St Helens Hills sample, UTGD124871; (G–L) Ocean Beach, Strahan, samples UTGD124886–91 respectively; (M) *Aurora Australia* sample, UTGD78185; (N) Penguin sample, UTGD76649.

SAMPLES TRAWLED BY CSIRO

UTGD66532 — offshore northwestern Tasmania

Lithology

Grey-green, nonbedded marl with minor bryozoan and mollusc content. When dried it is quite hard but disaggregates readily, producing very small residue coarser than 125 microns, with high proportion of clay and very well preserved foraminiferids, very dominantly planktonic.

Age

This is the sole CSIRO specimen from offshore northwestern Tasmania — from the West Tasmanian Shelf of Jones & Holdgate (1980). The sample is from approximately one nautical mile (1.85 km) south of the western end of shallow seismic profile Line 28 illustrated on figure 4 of Jones & Holdgate (1980). Although the correlation is imperfect, it suggests that the sample is part of the sequence of older rocks which appears to outcrop at this locality and to form the continental slope. In oil exploration well Clam-1, these were taken to be "hard brown limestone of Miocene age" (Port Campbell Limestone equivalent) (Jones & Holdgate 1980).

Biostratigraphic interpretation of this sample is ambiguous, and several samples were processed. Sediments of at least two ages are present, but whether they were mixed by dredging or geological factors cannot be ascertained. The two ages are based on ranges of well-known planktonic species and of a benthic species which has not been recorded from Tasmania before.

The mixed planktonic fauna is characterised by a low diversity of planktonic species which are dominated by *Globigerina bulloides* d'Orbigny, small globigerines and *Globorotalia scitula* (Brady). Keeled globorotalids are rare. A single specimen of *Orbulina universa* d'Orbigny was recovered but is taken as possible contamination and, thus, not significant stratigraphically. The fauna lacks sphaeroidinellids, pulleniatinids, hastigerinids or even the more complex variants of *Globigerinoides trilobus* (Reuss). The benthic fauna comprises 40% of the assemblage and is diverse but composed mostly of species that are not age diagnostic.

The younger fauna contains rare *Globorotalia inflata* (d'Orbigny), *G. truncatulinoides* (d'Orbigny) and *G. tosaensis* Takayanagi & Saito (differentiated from *G. truncatulinoides* by being more heavily thickened, possessing a less open umbilicus and less well-developed keel). This fauna is consistent with deposition during the earliest Pleistocene N22 (*Globorotalia [G.] truncatulinoides truncatulinoides* Partial-range Zone of Blow 1969).

Several specimens of *Globorotalia miozea* Finlay also are present and indicate that at least part of the fauna is Early to Middle Miocene, N7–N15 (*Globigerinatella insueta–Globigerinoides quadrilobatus trilobus* Partial-range Zone to *Globorotalia continuosa* Consecutive-range Zone of Blow 1969).

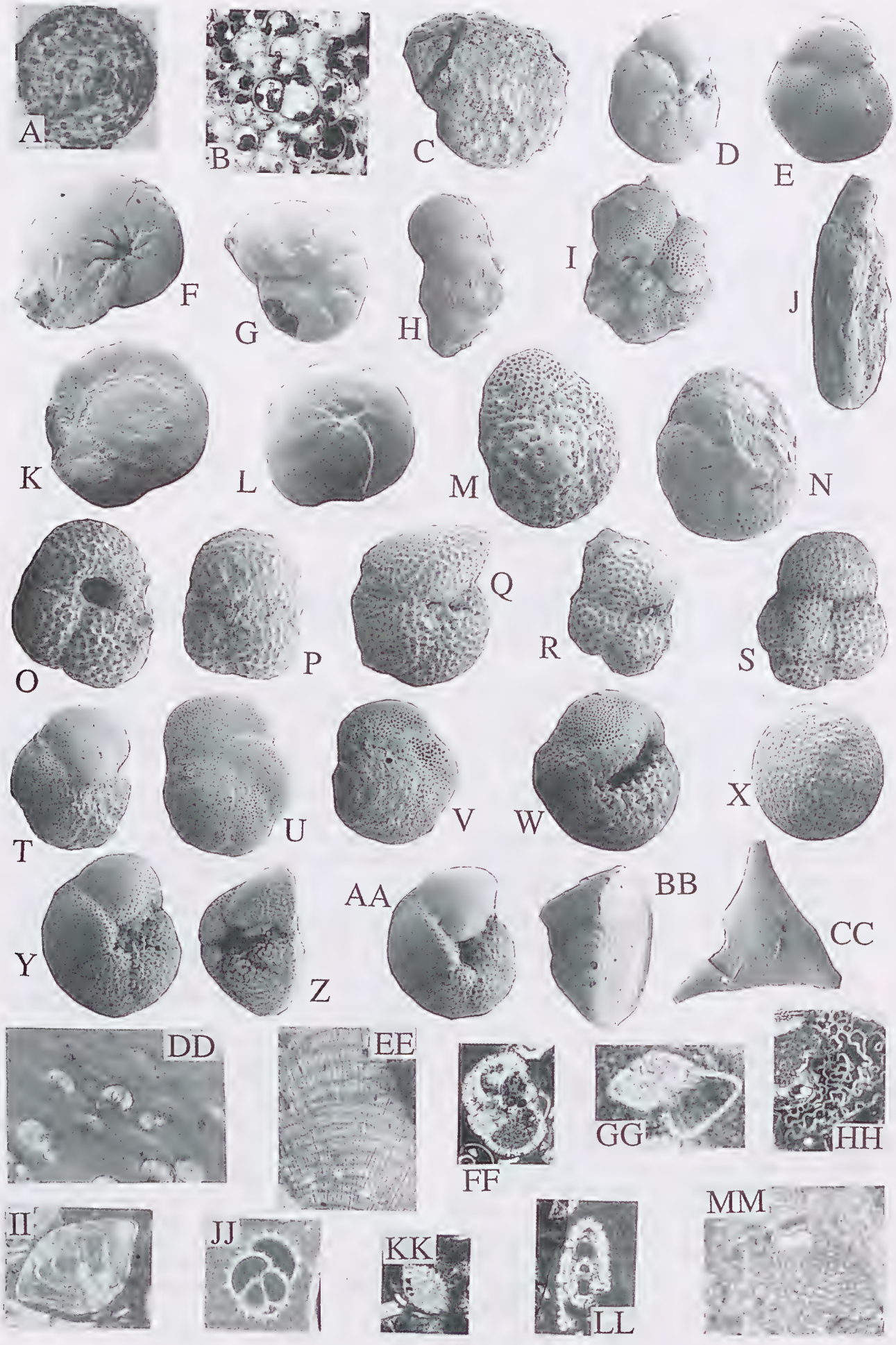
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PLATE 1

Several well-preserved specimens of *Cibicidoides notocenicus* (Dorreen) were recovered and originally identified as *C. mexicanus* (Nuttall). It seems that the two forms may be identical. *C. mexicanus* has a range from latest Eocene to Early Miocene (P16–N5 of Blow 1969) (Van Morkhoven *et al.* 1986), and thus it represents a time period not represented by the planktonic faunas. It occurred in middle and lower bathyal depths (600–2000 m) and, thus, should co-occur with abundant contemporaneous planktonic forms.

The age of the older fauna is not well constrained but probably belongs to the earlier part of the N7–N15 interval given above, and is here taken as later part of the Early Miocene (N7–N8, if the New Zealand range of *C. notocenicus* is to be followed).

Palaeoenvironment

UTGD66532 contains material from several ages and several different marine environments of deposition which are difficult to isolate. The sample locality now lies in 560 m water depth, but all faunas are consistent with accumulation in a mid- to outer-continental shelf depth. The 58% planktonic content suggests some subsidence since deposition. Comparison with the distribution of individual species and species groups discussed by Bé & Hutson (1977) indicates that the fauna is most similar to the living subpolar assemblage or the polar/subpolar fossil assemblage and that the waters at this location were colder in the past than they are now. The low diversity, virtual absence of keeled globorotalids and lack of many other groups common elsewhere also suggest that the water temperature was low during all intervals of deposition.

UTGD66533 — offshore eastern Tasmania

Lithology

Pale, well-sorted, massive bryozoal calcarenite described as "rocks from a coral patch", yielding large residue coarser than 125 microns. Some iron staining present and some foraminiferid chamber lumina filled with secondary iron oxide (Fe/Mn?). This occurrence may be similar in character to that of phosphates with goethite recorded by Jones & Davies (1983) in samples 2121 and 2126 from northwestern Tasmania. All carbonate grains are significantly overgrown, varying from light frosting to severe overgrowth on echinoderm fragments.

Additional fauna is very diverse in benthos and dominated by bryozoans, but also alcyonarians, bivalve fragments, rare, small, ribbed brachiopods, isocrinoid ossicles and echinoid spines.

PLATE 1

(A) Sherbornina cuneimarginata *Wade, Penguin, UTGD124959, equatorial section, ×65*.*
(B) Planorbulinella inaequilateralis *(Heron-Allen & Earland), Penguin, UTGD124960, equatorial section through embryonic chambers, ×125.*
(C) Operculina *sp. A of Carter (1964), from UTGD66534 off northeastern Tasmania, UTGD124961, ×36.*
(D, E) "Valvulineria" kalimnensis *(Parr), Penguin, UTGD124962, ventral and dorsal views, ×55.*
(F) Astrononion centroplax *Carter, southeastern Tasmania, UTGD124964, ×50.*
(G) Astrononion australe *Cushman & Edwards, Penguin, UTGD124965, ×90.*
(H) Karreria maoria *(Finlay), from UTGD66534 off northeastern Tasmania, UTGD124966, dorsal view, ×55.*
(I) Carpenteria rotaliformis *Chapman & Crespin, southeastern Tasmania, UTGD124963, dorsal view, ×24.*
(J) Crenulostomina banksi *Quilty, from southeastern Tasmania, UTGD124967, lateral view, ×30.*
(K, L) Cibicidoides notocenicus *Dorreen, offshore northwestern Tasmania, dorsal and ventral views, UTGD124968, (K) dorsal ×35, (L) ventral ×38.*
(M, N) Globorosalina scabricula *(Chapman), Penguin, dorsal and ventral views, UTGD124969, ×38.*
(O) Globigerina woodi *Jenkins, from off northeastern Tasmania, UTGD124970, ventral view, ×90.*
(P) Globigerina connecta *Jenkins, Penguin, UTGD124971, ventral view, ×130.*
(Q) Globoquadrina dehiscens *(Chapman, Parr & Collins), off northeastern Tasmania, UTGD124972, ventral view, ×105.*
(R, S) Globorotalia nana *Bolli, off southeastern Tasmania, UTGD124973, ventral and dorsal views, ×90.*
(T, U) Globorotalia scitula *(Brady), offshore northwestern Tasmania, UTGD124974, ventral and dorsal views, ×60.*
(V, W) Globorotalia miozea *Finlay, offshore northwestern Tasmania, UTGD124975, dorsal and ventral views, ×70 and ×65 respectively.*
(X) Praeorbulina glomerosa circularis *(Blow), offshore northeastern Tasmania, UTGD124976, ×105.*
(Y, Z) Globorotalia tosaensis *Takayanagi & Saito, offshore northwestern Tasmania, UTGD124977, ventral and oblique apertural views ×70 and ×65 respectively.*
(AA, BB) Globorotalia truncatulinoides *(d'Orbigny), off southeastern Tasmania, UTGD124978, ventral and oblique dorsal views, ×55 and ×80 respectively.*
(CC) Triangulina aequilateralis *Quilty, off southeastern Tasmania, UTGD124979, ×80.*
(DD–MM) Early Middle Miocene, Ocean Beach Strahan, UTGD124886. (DD) Mesophyllym/Lithophyllum *sp., ×25; (EE)* Lithophyllum *sp., ×50; (FF)* Carpenteria *cf.* rotaliformis *Chapman and Crespin, ×25; (GG)* Globorotalia scitula *(Brady), ×95; (HH)* Acervulina inhaerens *Schultze, ×27; (II)* Cibicides *sp., ×60; (JJ) spinose buliminid, ×100; (KK) Small* Elphidium *sp. indet., ×25; (LL) Large* Elphidium *sp. indet., ×25; (MM)* Gypsina globulus *(Reuss), ×55.*
** Most magnifications rounded to the nearest 5×.*

Age

The poorly preserved foraminiferid fauna is difficult to identify with certainty and, thus, the rock cannot be dated precisely. The benthic component (20–25% of the fauna) contains *Elphidium crespinae* Cushman, *Cibicides perforatus* (Karrer), *Gaudryina convexa* (Karrer) and *Pseudoclavulina* cf. *anglica* Cushman, all of which are known from Early Miocene sediments in southeastern Australia, and some range into the Middle Miocene in Tasmania and even younger in New Zealand. The early Miocene age assignment is consistent with the presence of common *Globigerina* species (including *G. connecta* Jenkins), which dominate over the benthic component. Other planktonic genera are absent. There is no evidence of reworking. A few Quaternary species, including *Globorotalia truncatulinoides,* are present and probably result from some mixing during dredging.

Although the age is not well constrained, the sediment is estimated to be Early Miocene and probably equivalent to the Fossil Bluff section. This is the interval within the Early Miocene that seems to have had water temperature conditions that yielded planktonic foraminiferid faunas with composition and diversity similar to those listed here (Quilty 1972).

Palaeoenvironment

The fauna in UTGD66533 is so poorly preserved that even the planktonic/benthic ratio cannot be estimated accurately. Based on the low diversity and domination of the planktonic content by hispid *Globigerina* spp., it was deposited in cool water conditions.

The sediment is lithologically similar to some described from the Marrawah region (Quilty 1972), which also have similar faunal composition, benthic and planktonic foraminiferid fauna and preservation, even if not age. They probably accumulated in similar palaeoenvironment on the inner to middle continental shelf, at depths of about 100 m or less, and at sites lacking significant sediment input. The sediment is well sorted, suggesting some current action, but there is no obvious abrasion of the foraminiferid tests, although preservation is inadequate to state this definitively. The sediment was recovered from over 1100 m and clearly has moved to its present depth, suggesting some continental margin slumping or downfaulting since the end of the Early Miocene.

UTGD66534 — offshore eastern Tasmania

Lithology

Massive white chalk which yielded a relatively large, well-preserved residue coarser than 125 microns. Bryozoa dominant, with echinoids and foraminiferids constituting a small component. No obvious terrigenous detrital element.

Age

Approximately 20% of the foraminiferid fauna is composed of planktonic species, including *Praeorbulina glomerosa circularis* (Blow), *Globoquadrina dehiscens dehiscens* (Chapman, Parr & Collins), *Globorotalia miozea* Finlay, *Globigerina decoraperta* Takayanagi & Saito, and *G. woodi woodi* Jenkins. A single specimen of a form very similar to *Globorotalia puncticulata* (Deshayes) was found and appears to be out of place. No *Globigerinoides* spp. were recovered. Benthic forms include *Operculina victoriensis, O.* sp. (of Carter 1964), *Cibicides mediocris* Finlay, *C. perforatus* (Karrer) (dominant benthic), *Karreria maoria* (Finlay), *Alabamina tenuimarginata* (Chapman, Parr & Collins) etc. It is a diverse fauna with low dominance.

Both planktonic and benthic species indicate an age on the Early–Middle Miocene boundary, that is N8 (*Globigerinoides sicanus–Globigerinatella insueta* Partial-range Zone) or N9 (*Orbulina suturalis–Globorotalia peripheroronda* Partial-range Zone of Blow 1969).

Palaeoenvironment

UTGD66534 is a warm, clear water, inner continental shelf sediment deposited in a low energy environment off a coast of low sediment input. It seems to have been deposited during an episode of high sea level, represented by sediment around most of the Australian coastline. It was recovered from 870 m and, thus, appears to be considerably below where it was deposited, perhaps by as much as 800 m, indicative of tectonic subsidence of approximately that amount.

UTGD66535, 66536 — offshore eastern Tasmania

Lithology

UTGD66535 white chalk; 66536 indurated grey, non-bedded marl. Residue coarser than 125 microns from 66535 small and dominated by foraminiferids and sponge spicules, with minor bone fragments, ostracods and alcyonarian spicules. That from 66536 larger and dominated by bryozoa and two types of calcareous worm tubes. Echinoid spines and small gastropods subordinate.

Age

The samples are Quaternary in age, based on the presence in each of *Globorotalia truncatulinoides truncatulinoides* (d'Orbigny), the index species for the Quaternary. Differentiation of the two Quaternary zones in the Blow (1969) scheme is not possible with the material available. Both samples consist of high diversity, low dominance benthic faunas with 28% and 71% planktonics respectively. Pulleniatinids and sphaeroidinellids are absent.

Palaeoenvironment

While UTGD66535 and 66536 are both Quaternary in age, in other ways they are very different. UTGD66536 comes from farther offshore and from deeper water. Thus, it would be expected to contain a higher percentage of planktonic forms in the foraminiferid fauna and benthic

forms indicative of deeper water deposition. In fact the converse is true. It contains less than 30% planktonic species, and almost half the benthic fraction is composed of miliolid forms, normally associated with reasonably shallow, inner shelf conditions of deposition. *Textularia* cf. *hayi* Karrer is the dominant benthic.

In contrast, UTGD66536, which is at present closer inshore and in shallower water, contains over 70% planktonic forms and a diverse planktonic species list. The benthic forms are diverse, and dominance (Walton 1964, Quilty 1972) is low, consistent with an outer continental shelf–upper continental slope site of accumulation.

The differences between foraminiferid faunas in UTGD66535 and 66536 may have been caused by deposition during glacial intervals (when sea level was approximately 130 m lower than now, ocean waters cooler and planktonic faunas less diverse; UTGD66536) and interglacial (when sea level was high, the ocean warmer and planktonic faunas more diverse; UTGD66535). Such conditions alternated during the Quaternary on a regular 100–120 ka cycle, perhaps in response to Milankovich forcing (Imbrie 1984, Goodess *et al. 1992*).

ST HELENS HILLS

The sample was studied from one large thin section of UTGD124871.

Lithology

Buff-coloured, highly indurated, matrix supported, micritic limestone with abundant and diverse macro- and microfossil content. Fabric of the sample highly disturbed, suggesting severe bioturbation or slumping to present locality. Most macrofossils broken. Echinoderm debris common; highly overgrown. Internal detail largely destroyed.

Age

The foraminiferid fauna is dominated by small, thin-walled globigerinids which are quite well preserved. These include *Orbulina universa*, *Globoquadrina* sp., *Globigerinoides quadrilobatus* (d'Orbigny), *Globoquadrina altispira* s.l., *Sphaeroidinellopsis* sp. (this appears not to be *S. dehiscens*, as no second aperture could be seen on the many sections encountered and the most similar form is *S. subdehiscens subdehiscens* Blow), *Globorotalia* (probably *G. tumida* [Brady]), *Globorotalia* (of the *G. scitula* type), *Globigerina* (of the thick-walled, three-chambered type such as *G.woodi*), *G. venezuelana* and possibly *Pulleniatina* (of the *P. primalis* type). Keeled and nonkeeled globorotalids are rare. Also present is an unidentified highly spinose *Globigerina*.

The composition of the fauna suggests a Late Miocene age (N18, *Globorotalia tumida tumida–Sphaeroidinellopsis subdehiscens paenedehiscens* partial-range zone of Blow 1969).

Palaeoenvironment

Deposition occurred in fully marine conditions adjacent to a source of coarse macrofauna, in water deep enough for the dominant sediment input to be pelagic. There is very little terrigenous material other than in the micritic fraction. This indicates either that runoff was low, or that the site of deposition was isolated from the mainland by a deeper water region. Water temperature was temperate, similar to the present-day environment.

AURORA AUSTRALIS SAMPLE

Site of deposition

Echo sounder information suggests that the site is on a flat-topped submarine plateau at about 800 m. Between the plateau and the continental shelf edge there is a deeper channel.

Lithology

A mixture of bryozoal calcarenite fragments, up to 30–40 mm in size, broken from parent rock during coring, and minor soft "modern" sediment. The more lithified sediment is compact, white, moderately lithified, well-sorted, bryozoal calcarenite, apparently unbedded. It contains abundant echinoderm debris, alcyonarian remains and bryozoa. Small, ribbed brachiopods rare. Most fossils well preserved but echinoderm debris commonly substantially overgrown. Terrigenous detritus a very minor component of the 125–250 micron fraction. Calcarenite surface marked by brown iron staining in zone about 5 mm thick, suggesting it marks a hardground on which younger sediment is accumulating. Because of the mixed nature of the sediment, samples reported here were carefully chosen and washed before crushing and processing, to ensure that there has been no mixing of the younger with the older.

The well-lithified sediment is overlain by soft sediment, which is carbonate rich with abundant foraminiferids.

Age

In the well-lithified sediment, foraminiferids constitute a small volume of the residue but are well preserved. Planktonic species are a very minor component (much less than 1%) of the fauna and only *Globigerina woodi, G. bulloides* and *Globorotalia nana* Bolli were recovered. Benthic forms are diverse and dominated by *Cibicides perforatus*. Few of the key species in the southeastern Australian biostratigraphic schemes of Carter (1958, 1964) are present, but *Astrononion centroplax* Carter, *Carpenteria rotaliformis* Chapman and Crespin, *Notorotalia howchini* (Chapman, Parr & Collins) and *Elphidium crespinae* Cushman, together with the planktonic species listed above, suggest that the fauna is from the earlier part of the Early Miocene (or perhaps very latest Oligocene). The problematic form *Triangulina aequilateralis* Quilty (Quilty 1970) was described from the earliest Miocene of Cape Grim and also is found here but is very rare.

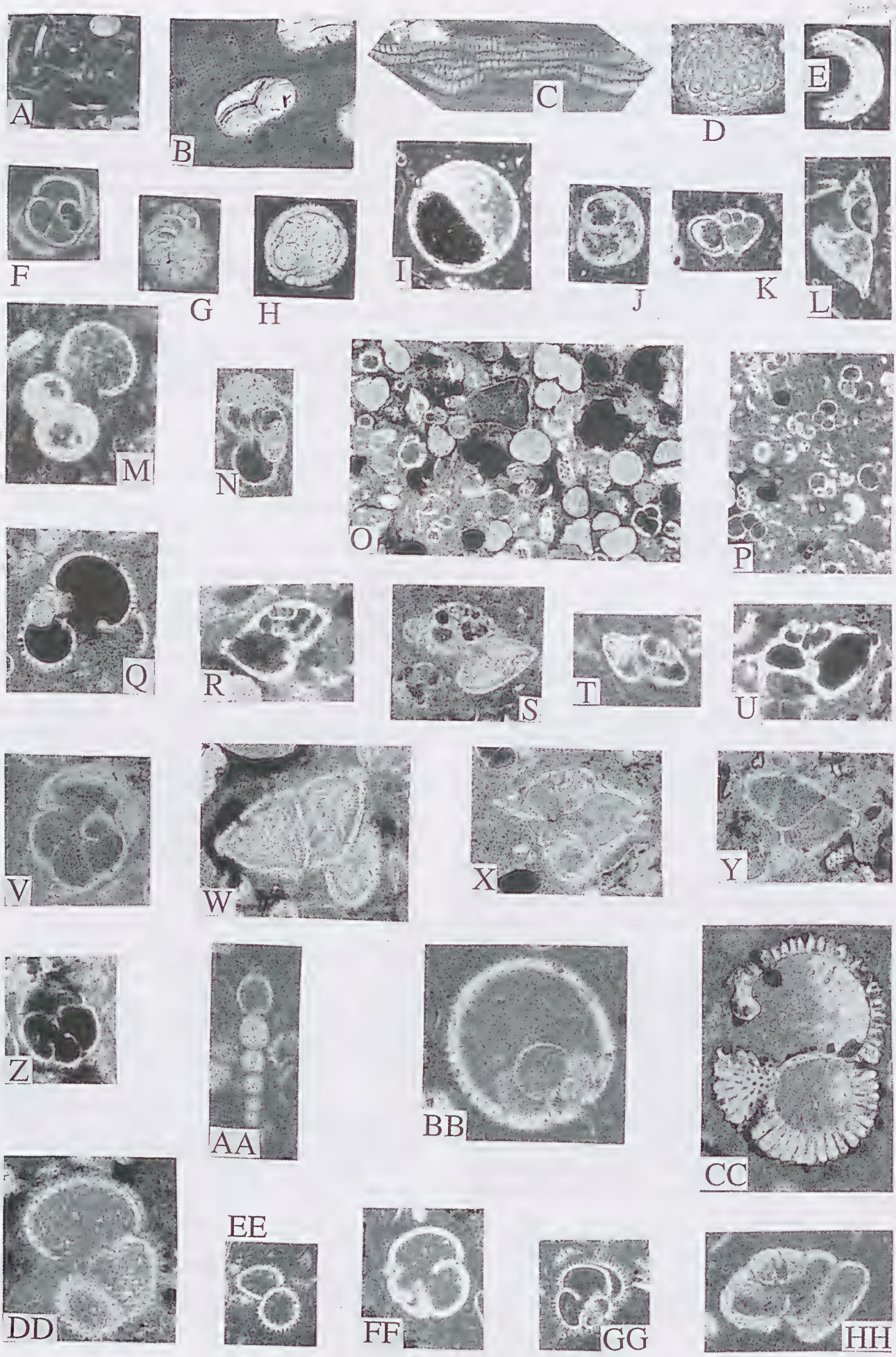

PLATE 2

The overlying younger sediment was not well sampled by the core, but planktonic species constitute over 90% of the foraminiferid fauna and include abundant *Globorotalia inflata* and rare *G. truncatulinoides,* indicating a Quaternary age. Otoliths include those from myctophids (lanternfish) and others.

This sample provides the first palaeogeographic evidence from the pre-Quaternary Cenozoic of southeastern Tasmania and is the first step in redressing the problem of lack of samples of much of the Tertiary, noted by Colhoun in Burrett & Martin (1989: 409).

Palaeoenvironment

The Early Miocene sediment was deposited in shallow water. It has a very low planktonic content and probably accumulated off a coast with low runoff. Water depth was probably less than 20 m, and that depth probably precludes the full diversity of planktonic forms being incorporated. There is not enough information to comment on water temperature at the time, other than that there are no indices of subtropical/tropical or even warm temperate conditions. This perhaps supports an earlier, rather than a later Early Miocene age determination.

The Quaternary sediment is characterised by sinistrally coiled G*loborotalia truncatulinoides,* which indicates deposition in cool water.

OCEAN BEACH SAMPLES

One thin section was studied from each of the six rock samples collected. This material was not recorded in the review of Macquarie Harbour Graben sediments contained in Baillie & Corbett (1985). Lithology is variable from bryozoal calcarenite to conglomerate with interstitial bryozoal debris. Three separate rock types appear to be present and a fourth is a mixture of two as a conglomerate.

UTGD124886

The most complex of six samples recovered. Conglomerate with well-rounded, high sphericity pebbles of calcarenite to about 30 mm, embedded in grey matrix which seems to represent significantly younger, shallower water phase.

Older material consists of yellowish to reddish-brown, uniformly medium-grained calcarenite. Foraminiferids the dominant fossil group, but some bryozoa, echinoid spines and rare calcareous algae also present. Benthic foraminiferids subordinate to planktonics.

The older material is early N9 in age, based on the presence *inter alia* of *Praeorbulina, Orbulina universa, Globoquadrina, Globorotalia scitula* and *Globigerina* of the *woodi* group. Small, thin-walled, four-chambered globigerinids also are common.

The grey matrix is much coarser, poorly sorted and highly porous. Where the porosity is low, it is due to the filling of the interstices by uniform, very fine, grey micrite. This phase consists of highly fragmented bryozoan calcarenite with common calcareous algae, serpulids and broken mollusc fragments. Foraminiferids are less common than in the reddish phase and benthics are dominant over planktonics.

This phase is much younger than the framework of the pebbles and the planktonic foraminiferid fauna less common. Benthic forms include *Elphidium* spp. (both large and small species), *Carpenteria* cf. *rotaliformis, Acervulina inhaerens, Notorotalia* and miliolids. This phase seems to be Late Miocene, N18 in age.

UTGD 124887

Grey, roughly laminated limestone dominated by calcareous algae, bryozoans and gastropods, with other minor molluscs and echinoids. Interstices filled with very fine (but not micritic) sediment, including some fine, angular, terrigenous material and sponge spicules. Foraminiferids identified, while uncommon, come from this lithology and include

PLATE 2

Early Middle Miocene, Ocean Beach Strahan, western Tasmania.
(A–G) From UTGD124487. (A) Sponge spicules in rock thin section, ×25; (B)* Mesophyllum/Lithophyllum *sp., ×70; (C)* Lithoporella *sp., ×65; (D)* Gypsina globulus, *×55; (E)* Sherbornina *sp., ×65; (F)* Globoquadrina dehiscens *(Chapman, Parr and Collins), ×65; (G)* Elphidium *sp., ×65.*
(H–I) From UTGD124888. (H) Praeorbulina glomerosa *Blow, section through embryonic chambers, ×70; (I)* Orbulina universa *d'Orbigny, ×45.*
(J–N) From UTGD124889. (J) Globigerinita *sp., ×70; (K)* Globorotalia scitula *(Brady), ×80; (L)* Globorotalia *cf.* conoidea *Walters, ×65; (M)* Globigerinoides quadrilobatus *(d'Orbigny), ×105; (N)* Globigerina angustiumbilicata *Bolli, ×200.*
(O–Z) From UTGD124891. (O) Lithology showing phase with abundant glauconite grains, ×45; (P) Lithology showing abundance of planktonic foraminiferids, ×50; (Q) Globigerina angustiumbilicata, *×100; (R, S)* Globorotalia conoidea/miozea, *vertical sections, ×120 and ×150 respectively; (T)* Globorotalia scitula *(Brady), vertical section, ×105; (U)* Globorotalia conoidea *Walters, ×110; (V–Y)* Globorotalia (?) conomiozea *Kennett, (V) equatorial section, ×110, (W-Y) vertical sections, ×110, 160 and 110 respectively; (Z)* Globoquadrina *sp., ×190.*
(AA–HH) All Late Miocene, St Helens Hills, UTGD124871. (AA) Stilostomella *sp., longitudinal section, ×30; (BB)* Orbulina universa, *×110; (CC)* Sphaeroidinellopsis *sp., ×105; (DD, EE)* Globoquadrina *cf.* dehiscens *(Chapman, Parr & Collins), vertical sections, ×115 and ×45 respectively; (FF)* Globigerina venezuelana *(Hedberg), vertical section, ×45; (GG) highly spinose globigerinid, vertical section, ×40; (HH)* Globorotalia scitula, *×110.*
** Most magnifications rounded to the nearest 5×.*

Sherbornina, Globoquadrina dehiscens, small *Elphidium* and *Gypsina globulus.* These are not age diagnostic but are consistent with the Middle Miocene age identified in some of the other Ocean Beach samples. This rock has been burrowed to a minor extent and the burrows are infilled with angular detrital material from which no fossils have been recovered.

UTGD124888-124890

Each of three samples consists of single lithology which is reddish or yellowish brown, highly calcareous with common bryozoans, minor calcareous algae, weak bedding accentuated by alignment of the bryozoans, and matrix supported with abundant, thin-walled globigerinids. Fine, curved fragments are common and may be ostracod or pteropod remnants. Fragmentation of components common, but rounding not evident.

UTGD124888 contains *Orbulina universa, Praeorbulina glomerosa, Globorotalia* cf. *miozea, G. scitula, Globoquadrina* etc.

UTGD124889 and 124890 very similar to 124888 but bedding less obvious and sponge spicules abundant in the matrix. Pteropods are identifiable in this slide only. Foraminiferids, while abundant, do not include age diagnostic forms. *Globorotalia* cf. *conoidea* is present. 124890 contains what appears to be *Globorotalia conomiozea,* which would indicate an age younger than the early Middle Miocene documented above for other samples from Ocean Beach.

UTGD124891

Sand-sized pellets or tubular structures, 2–5 mm in diameter, which have a marked concentric structure. Terrigenous material not abundant, but silt-sized grains are angular and coarser grains well rounded. Other fossil debris includes abundant but poorly defined small sponge spicules, echinoid spines and broken and rounded bivalve fragments. Sample also has patches dominated by rounded glauconite grains, interstitial between the concentric structures. *Globorotalia (?) conomiozea* also is present, even quite common, in this sample.

Age

Foraminiferid and other faunas vary greatly from sample to sample but are generally dominated by small, thin-walled globigerinids. Keeled globorotalids are rare. Benthic forms include *Elphidium, Karreria,* gavelinellids, and occasionally abundant miliolids. Pulleniatinids and other Late Miocene and Quaternary planktonic forms are absent. The foraminiferid fauna is listed on table 2. Calcareous algae are a feature of most specimens and include *Mesophyllum/ Lithophyllum* and *Lithoporella.*

UTGD124887 contains *Orbulina universa* (several sections) and *Praeorbulina glomerosa,* showing that this specimen, at least, is very early Middle Miocene (early N9, *Orbulina suturalis–Globorotalia peripheroronda* Partial-range Zone of Blow 1969). *Praeorbulina* has also been seen in a thin section of UTGD124886. Other specimens contain abundant thin-shelled forms including a common five-chambered globigerinid that is probably *G. angustiumbilicata,* and *G. woodi, Globorotalia scitula, G.* cf. *conoidea* Walters, *G. miozea, Sphaeroidinellopsis* sp., *Globoquadrina altispira, Globigerinita* sp. and the benthic forms, *Sherbornina* sp., *Elphidium* spp., *Karreria maoria, Gypsina globulus* (Reuss), *Cibicides* cf. *perforatus, Textularia* sp., miliolids and buliminids. The absence of pulleniatinids from all samples suggests an age older than Late Miocene for the entire specimen collection.

A form that appears to be *Globorotalia conomiozea* is present in UTGD124890 and 124891. It is possible that two ages are represented in both the sample collection and in individual samples. In addition to the early Middle Miocene age documented here, it is possible that lithified Middle Miocene fragments have been reworked into the grey limestone which is Late Miocene, probably N18 (*Globorotalia tumida tumida–Sphaeroidinellopsis subdehiscens paenedehiscens* Partial-range Zone of Blow 1969). However, any suggestion of Late Miocene is very tentative.

Palaeoenvironment

The variation in lithology and fossil content suggests an origin in a "shallow" water, fully marine environment, at a time of high energy. Abundant calcareous algae in some specimens indicate a depth limit in the photic zone, perhaps 70 m or shallower. Rounding and breakage of fossils and the abundance of coarse terrigenous material are also consistent with this hypothesis but probably support a depth of deposition considerably less than 70 m. Other specimens lack the algae and have high proportions of planktonic species, which suggests a deeper water, perhaps outer continental shelf depth of deposition. A significant part of the breakage seems due to postdepositional compaction effects.

The red/brown material has a higher planktonic foraminiferid content, suggesting deeper water deposition (still within the photic zone to judge from the calcareous algae) and perhaps a period of exposure to allow development of a ferruginous character and also erosion to generate rounding and redeposition. The grey, bryozoan/mollusc/ algae rich content is a younger, shallower water, higher energy component.

COMPARISON WITH MODERN TASMANIAN SHELF SEDIMENTS

Jones & Davies (1983) summarised what is known of the distribution of modern sediments on the Tasmanian continental shelf and through most of Bass Strait. For that study, 365 localities were sampled and analysed for grain size, composition, heavy mineral content etc. This collection of samples has provided the basis for other studies such as that by Rao & Adabi (1992, and references therein). The modern material studied by Jones and Davies and by Rao and Adabi has in common with older Neogene sediments around Tasmania that it seems generally to be cold water carbonate dominated, with the exception of one interval at the close of the Early Miocene and earliest Middle Miocene, when conditions were much warmer. Unfortunately, little attention was given by Jones & Davies (1983) to biogenic content other than for molluscs and pollen (three samples

only), although reference was made to unpublished foraminiferid data of Taylor and Mee, which indicate that the benthic component is quite different from that recorded from the older samples. In contrast to the modern samples recorded by Jones & Davies (1983), the material recorded herein generally contains little molluscan debris. Jones & Davies' samples were generally from less than 100 m water depth, a few to about 200 m, and only one unsuccessful attempt (locality 2029) was made to obtain material from significantly deeper waters — 823 m. This latter sampling was within a few kilometres of UTGD66535 (see below). Similarly, sample location 2119 in 170 m was within a few kilometres of UTGD66532.

Jones & Holdgate (1980) referred to Miocene sediment from shallow depth in the oil exploration well Clam-1, off northwestern Tasmania, and it is probable that what has been recorded here from UTGD66532 is part of that sequence which outcrops on the seafloor.

Exon *et al.* (1992) recorded sediments from core, grab and dredge samples along the west coast of Tasmania. Dredge samples in areas close to those examined for this paper are Cretaceous. Cores 45 and 46 contained Late Pliocene sediments deposited under cold surface water conditions. Core 40 consisted of shallow water Early Miocene overlain by Quaternary. The grab samples contained only modern material and will be discussed no further.

TASMANIAN NEOGENE MARINE SEDIMENTATION PATTERNS

By the beginning of the Miocene, Australia and Antarctica had separated (Veevers *et al.* 1991) sufficiently to allow open circulation, both shallow and deep, between the continents from the Indian to Pacific Oceans, as part of a circumpolar system that exists today (see Kemp 1978,

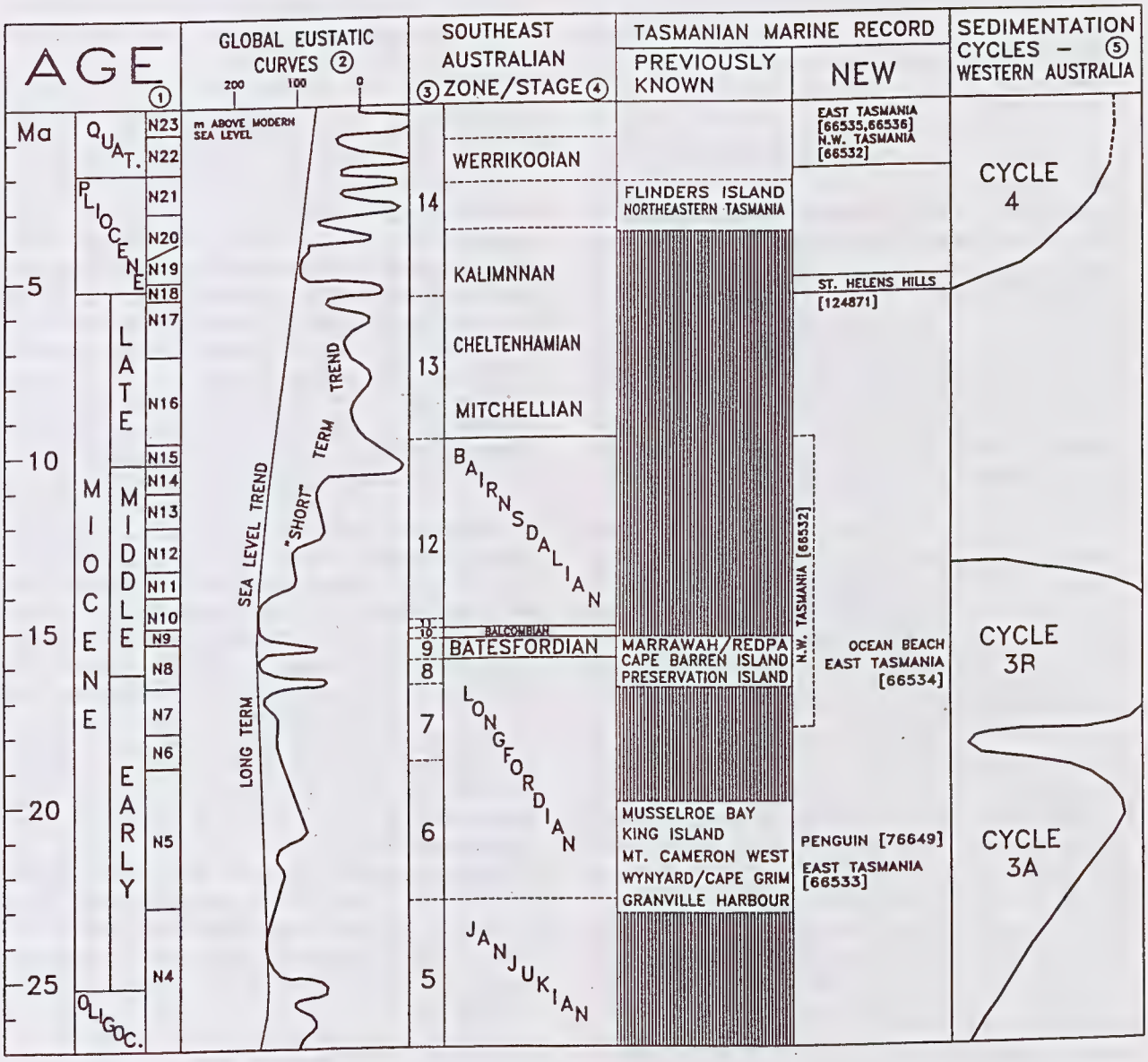

FIG. 3 — Integration of new data into general correlation scheme for all Tasmanian marine sediment sections. (1) Planktonic foraminiferid zonal scheme of Blow (1969). (2) Correlation of age and global eustatic curves taken from Haq et al. *(1987). (3) Carter (1958) Faunal Unit scheme. (4) Correlation of Faunal Units and Australian stages from Abele in Douglas & Ferguson (1976). (5) Western Australian sedimentation cycles from Quilty (1977).*

Veevers 1984). For the first time, Australia became independent of the direct influence of Antarctica, in contrast with conditions earlier. There were marine conditions and shallow water flow from west to east through Bass Strait. Tectonically, the region was relatively inactive, other than for changes in latitude due to seafloor spreading. Volcanism was active onshore in Tasmania during the Miocene (Sutherland & Wellman 1986) and also intruded into offshore marine sequences (Burrett & Martin 1989). It seems, therefore, that the principal influences on Tasmanian sea-level change and climate were global rather than purely local.

Only a small proportion of Neogene time is represented by marine sediments recorded here in and around Tasmania and, thus, any reconstruction of Neogene history based on the marine record alone is incomplete and biassed towards short intervals of time. This is in contrast with the situation in much of southeastern Australia, where more continuous sections are known, and is probably due to the lack of basinal structures in the Cenozoic of Tasmania, other than graben, and control of marine sedimentation patterns by eustatic sea level variation.

Study of all known sections and records from many isolated sections reinforces the indications, outlined in Quilty (1972, 1985a, b), that the discontinuous Tasmanian marine record reflects a series of episodes of deposition in the earliest Miocene, very late in the Early Miocene and/or earliest Middle Miocene, Early and Late Pliocene and at different times through the Quaternary. Most of the pre-Quaternary episodes are represented by several sections and isolated samples. The Late Miocene is represented in only one sample seen to date and that was deposited in much deeper water conditions than sediments of other ages. The earlier part of the Middle Miocene is identified only from those samples deposited in N9 time, probably as a continuation of the episode of deposition in the latest Early Miocene. This study indicates that the latest Middle Miocene (N14/15 of Blow 1969) may be present. This is unusual in Australian Cenozoic sections.

The records appear to represent carbonate sedimentation during intervals of globally warmer water conditions and high sea level. These coincide generally with a similar sequence of episodes of deposition elsewhere around Australia, documented by Quilty (1977b, 1980b) and McGowran (1979) and McGowran & Li (1993). Figure 3 includes a compilation of the international eustatic sea-level curve produced by Haq *et al.* (1987), based on those of Vail *et al.* (1977). On what earlier authors have termed the short-term sea-level curve, there is shown to be a series of generally higher sea levels including one in the very Early Miocene (N4/5), a series of peaks at the Early/Middle Miocene boundary (including N8 and N9) and one in the Early Pliocene (N19/20). The Early/Middle Miocene events seem to represent the interval of highest Neogene sea level that also coincides, from the Tasmanian and other southern (McGowran & Li 1993), eastern (Quilty 1993) and western Australian evidence, with a time of very warm marine conditions, marked by carbonates and the presence, even in Tasmania, of large, subtropical or warmer foraminiferids such as *Lepidocyclina*. This probably was the interval of warmest conditions that surrounded Australia during the Cenozoic. Figure 3 also shows the Western Australian sedimentation cycles described by Quilty (1977b, 1980b). Cycles 3A and 3B have been identified in the Gippsland Basin (McGowran & Li 1993) and have been resolved into a more detailed transgression/regression record. This level of differentiation is at yet impossible in the Tasmanian sequence. The N14/15 record does not fit the pattern at all.

The earlier Miocene high sea-level event is not marked by warm water genera, such as *Lepidocyclina,* but does include the warm temperate (and warmer) genus *Operculina* at Penguin and at Doctors Rocks near Fossil Bluff. The fauna from southeastern Tasmania suggests cooler water than at Penguin/Doctors Rocks, perhaps due to different water masses operating. Kennett (1977) developed a scenario of circulation for the latest Oligocene, of cooler water from the south in southeastern Tasmania and warmer water from the west through Bass Strait. The results here indicate that this may have continued into the earliest Miocene. Kennett *et al.* (1985) suggested that the region was temperate in the Early Miocene, which is consistent with this interpretation. Sedimentation during this interval includes a significant noncarbonate component in the Fossil Bluff–Penguin area. Elsewhere, for example southeast of Tasman Island, and in Musselroe Bay (northeastern Tasmania), this was an interval of carbonate sedimentation.

The Pliocene sea-level high is relative only to sea levels immediately before and since and seems not to have been as high as during any of the Miocene events; nor is it represented by larger foraminiferid species of warm water aspect.

Thus, the Tasmanian marine sediment record, as far as it is known, is typical of what would be expected of a passive margin influenced by variations in sea level. The gaps in the sediment record dominate the stratigraphic column and appear to represent times of regionally low sea level. In most sedimentation cycles, the sediments seem to represent warm or relatively warm water sedimentation, and this seems to be regional in extent as noted above.

Loutit *et al.* (1983) and Kennett & Von der Borch (1985) summarised the Deep Sea Drilling Project contribution to palaeoceanography and water temperature for the southwest Pacific Ocean. Loutit *et al.* included data from Sites 279 and 281, which are southeast and south of Tasmania respectively, and quoted convincing evidence for an Early Miocene that was warmer than the Middle and Late Miocene, with a major cooling event during the interval 15–13 Ma, consistent with the evidence preserved around Tasmania. They also differentiated two warm phases within the Early Miocene, at 20.5 Ma and 16.5 Ma although their data began at about 20.5 Ma, younger than the oldest material included in this paper. Kennett *et al.* (1985) referred to the lowest $\delta^{18}O$ of the Neogene as being in the latter part of the Early Miocene and, thus, consistent with this being the warmest water of the Neogene, in turn consistent with the indications for Tasmania of the *Lepidocyclina* fauna.

Sediments marking the earliest Miocene transgression (N4/5; Faunal Unit 6) are known from north (both west and east parts) and from offshore southeastern and northeastern Tasmania. In contrast, the latest Early Miocene–Middle Miocene (N8/9; Faunal Unit 8/9) sediments are recorded onshore only from Marrawah in far northwestern Tasmania, through CSIRO sample 66534, to Ocean Beach. Late Miocene and younger sections are poorly known, and more samples are needed before generalisations can be made. So far, they are known from Flinders Island and offshore northeastern Tasmania only, perhaps largely because of sampling peculiarities.

IMPLICATIONS FOR NEOGENE TECTONISM

Several of the samples examined in this study contain evidence of the depth of water at the time and site of deposition. The present water depth is often inconsistent with an hypothesis that suggests there has been no postdepositional vertical movement. For example, UTGD66534 was deposited in about 50 m water depth but now lies in 870 m and the *Aurora Australis* sample was deposited in less than 20 m but now lies in 810 m. Differences due to eustasy are much less than 800 m, suggesting that sediments at the locality have moved into deeper water either by slumping or continental margin downwarp or faulting. The differences are of the order of 400-1000 m, but no consistent trend with age is obvious. It is clear, however, that significant movement has taken place. Many more locations need to be sampled before any trend can be found reliable.

CONCLUSIONS

Samples studied in this paper all were deposited in the Neogene. The more samples are collected, the more it becomes clear that this interval is the one which is most important around Tasmania for marine Cenozoic deposition, because no marine foraminiferid faunas older than this are known from Tasmania onshore or offshore, except in sections penetrated during hydrocarbon exploration. These are from Bass Strait and from offshore west coast Tasmania (fig. 1).

The sediment record is consistent with intermittent deposition during intervals of high sea level on the global eustatic sea-level curves, such as those compiled by Vail *et al.* (1977) and Haq *et al.* (1987). It is further consistent with the history of deposition recorded from elsewhere around Australia. It further highlights the lack of information from the marine environment for most of the Middle and Late Miocene across southern Australia.

The warmest water conditions were at the close of the Early Miocene and earliest Middle Miocene, consistent with indications from earlier onshore studies (Quilty 1972).

None of the earliest Miocene faunas documented from the samples studied here represents a warm interval, although the presence of *Operculina* at Penguin and in UTGD66534 does indicate warmer conditions during deposition of those sediments than exist at present.

Neogene carbonate sedimentation occurred farther south on both eastern and western Tasmanian coasts than has been recorded previously.

Water temperature conditions during deposition varied from time to time, and the results available are consistent with southwest Pacific Ocean temperature history as documented by Kennett et *al.* (1985).

There has been significant postdepositional vertical movement of several hundred metres of some of the sediment sections.

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SPECIES COMPOSITION AND SEASONAL CAPTURE RATES OF TERRESTRIAL AMPHIPODS IN A LOWLAND AND HIGHLAND FOREST IN TASMANIA

by Andrew M. Walsh, Robert J. Taylor, Peter G. Cale and Raymond N. Brereton

(with four tables and five text-figures)

Walsh, A.M., Taylor, R.J., Cale, P.G. & Brereton R.N., 1994 (30:vi): Species composition and seasonal capture rates of terrestrial amphipods in a lowland and highland forest in Tasmania. *Pap. Proc. R. Soc. Tasm.* 128: 57–62. ISSN 0080–4703. Forest Practices Unit, Forestry Commission, 30 Patrick Street, Hobart, Tasmania, Australia 7000 (AMW, RJT, RNB); 260 Selby Street, Floreat Park, Western Australia, Australia 6014 (PGC).

Composition of the amphipod fauna and seasonal changes in captures in pitfall traps were compared at a lowland forest in northeastern Tasmania and three sites in highland forest in central Tasmania. The number of species at the highland sites (five) was greater than for the lowland area (two), possibly due to the greater development of the litter habitat and the moister, more humid conditions at the highland sites. Capture rates were correlated with temperature, but not rainfall, at both the lowland and highland areas. However, minium temperature was most significant for the highland sites, and maximum temperature was most significant at the lowland area. Captures at the highland sites were proportionally greater in autumn and lower in summer and showed a peak in October which was not present at the lowland area. Capture rates are most likely influenced by both activity levels and population size, as determined by seasonal reproductive patterns. It is, therefore, possible that the differences in the seasonality of captures at the highland and lowland areas may be related to different patterns of reproductive activity at the different altitudes.

Key Words: amphipods, capture rates, seasonality, climate, temperature, altitude, Tasmania.

INTRODUCTION

Tasmania contains a diverse assemblage of terrestrial amphipod crustaceans (family Talitridae) made up of at least 15 species (Friend 1987), most of which are found in the soil and litter. It is common to find up to five species in two or more genera in the same soil and litter sample. It has been hypothesised that competition for space rather than food regulates populations and that pairs of species differ in terms of vertical distribution, body size and breeding season (Friend & Richardson 1977). Such niche partitioning is partly facilitated by differences in humidity and temperature tolerances, resulting in a number of species coexisting in the same site but in different levels of the soil and leaf litter. Richardson & Devitt (1984) observed that on Mt Wellington *Mysticotalitrus cryptus* numbers declined sharply in the face of increasing numbers of *Keratroides vulgaris* in mid to lower altitude gullies, but at higher altitudes the two species coexisted, possibly due to the latter's competitive ability being reduced.

Terrestrial talitrids appear to be active at night and occur deeper in the soil and/or litter layer during the day (Friend & Richardson 1977, 1986). Activity can also be influenced by avoidance of detrimental environmental conditions, such as flooding (Friend & Richardson 1986), and capture rates can be influenced by climatic factors such as temperature (McColl 1975).

In this study, the composition of the amphipod fauna and monthly capture rates are compared between two areas in Tasmania that differ in altitude, rainfall and temperature.

METHODS

Study Areas

Central Plateau

This study area consisted of three sites on the Central Plateau of Tasmania: D'Arcys Bluff (AMG 4420 53291, elevation 880 m, NW aspect, 37 ha), Hornes Dam (AMG 4475 53196, 750 m, S aspect, 35 ha) and Butlers Road (AMG 4473 53164, 700 m, S aspect, 20 ha) (fig. 1). Jurassic dolerite underlies all three sites and forms a variably dense surface cover of Quaternary talus. Snowfalls are common in winter and snow can lie for several weeks on the ground at the D'Arcys Bluff site.

Vegetation at all three sites was tall, open forest dominated by c. 150–200-year-old *Eucalyptus delegatensis*, closed forest dominated by *Nothofagus cunninghamii*, or intermediates between the two types. Only small areas of closed forest were present, at Hornes Dam and Butlers Road. Shrub and ground cover varied within sites, depending on canopy cover, dryness and surface rock abundance. The ground in wetter areas was bare under denser canopies, while the treefern *Dicksonia antarctica* was common in wetter, more open areas.

Old Chum Dam

This study area of 500 ha was located in northeastern Tasmania (fig.1), on the southeast-facing slopes to the north of Old Chum Dam (AMG 5880 54540) and in forest southwest of the dam. Altitude varied from 100–250 m and the geological substrate present was Ordovician granite.

The main eucalypt present was *Eucalyptus obliqua*. *Eucalyptus amygdalina* was subdominant over much of the area and dominant in some flatter drainage lines. *Eucalyptus viminalis* was widespread but uncommon. Understorey on most upper and middle slopes was very open, being dominated by bracken *Pteridium esculentum*. The undergrowth

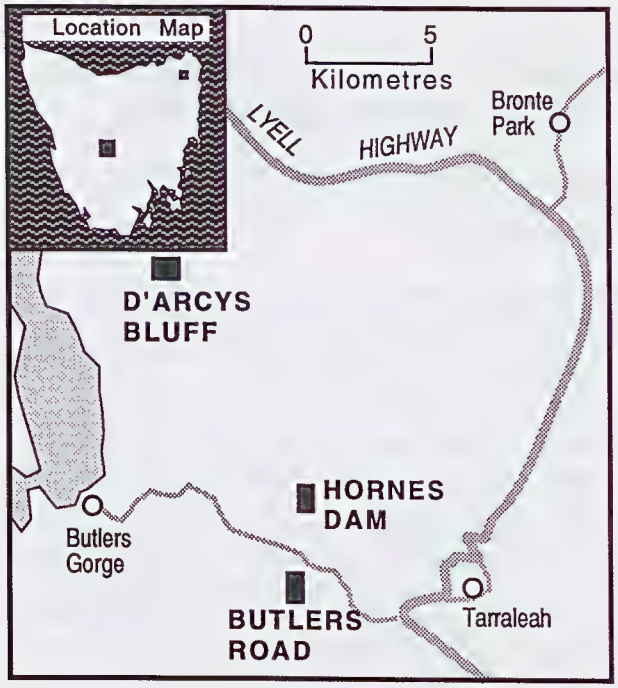

FIG. 1 — Location of the study areas. Inset: Old Chum Dam in the northeast and the Central Plateau sites in central Tasmania. Main map: the sites on the Central Plateau.

was shrubbier on slopes above creek lines and gullies with *Acacia verticillata, Olearia lirata* and *A. terminalis* being most common. On the south-facing mid to lower slopes, the soils were well drained and intermediate between wet and dry sclerophyll sites. Vegetation along creeklines was of two major types. Blackwood (*Acacia melanoxylon*) forest occurs along steep gullies and in some well-drained stream flats, with *Dicksonia antarctica, Olearia argophylla, Pomaderris apetala, Coprosma quadrifida* and *Bursaria spinosa* forming a dense, medium to tall shrub layer. The second type had an undergrowth dominated by dense, myrtaceous tea tree scrub, consisting of *Melaleuca squarrosa* and *Leptospermum scoparium,* and was associated with basins and soakages with impeded drainage and high soil moisture.

Climatic Data

For Old Chum Dam minimum and maximum daily temperatures and rainfall data were recorded on site during the census period. No climatic data were recorded for the sites on the Central Plateau. Instead, data for the town of Tarraleah near these sites (fig. 1) were obtained from the Bureau of Meteorology.

Pitfall Trapping

For the Central Plateau sites, 162 pitfall traps were used (30 at Butlers Road, 72 at Hornes Dam and 60 at D'Arcys Bluff) and at Old Chum Dam 180 pitfall traps. Each trap consisted of a plastic drinking cup (85 mm top diameter) placed into a buried section of PVC pipe so that the rim of the cup was flush with the ground surface and sheltered from rain by a plastic tray supported by small wooden sticks. At the Central Plateau sites, six traps were set out in a two-by-three-trap rectilinear grid at 10 m spacing between traps, with a total of 27 grids distributed over the three sites. At Old Chum Dam, a set of five of these pits was placed in two lines, one of three and another of two, with a spacing of 8–10 m between pits. At the start of a sampling interval, each trap was filled with c. 75 ml of 50% ethanol + 5% glycerol as a preservative. During the summer months, pits in open areas were given a little more liquid to allow for evaporation. Traps were set and collected over a period of two to three days, depending on the time of year, and were left open for seven days each month. Sampling was undertaken at the Central Plateau sites between December 1991 and November 1992, and at Old Chum Dam between April 1989 and May 1990. Recovery of samples was reduced, due to flooding of some traps from melting snow and removal of traps by native animals.

Data Analysis

Correlation analysis was used to examine similarities in the pattern of captures over months among species occurring in the same site and between the same species in different sites or areas. Only species and sites with sufficient numbers were analysed (the minimum used was 68 individuals captured over a 12-month period). Multiple regression was used to investigate the influence of minimum and maximum temperatures, rainfall and raindays on capture rates. Climatic data collected during the periods when pitfall trapping was undertaken were used in the analysis. Rainfall in the seven days prior to each month's trapping period was also used at the Central Plateau sites. These data were not available for Old Chum Dam. Numbers of amphipods captured were logarithmically transformed before regression analysis. Analysis of covariance was used to compare the relationship between temperature and capture rates of *Keratroides vulgaris* at Old Chum Dam and Central Plateau.

RESULTS

Five species were found at Central Plateau sites and two species were collected at Old Chum Dam (table 1). *Keratroides vulgaris* was dominant at all sites and was the only species present at both Old Chum Dam and the Central Plateau. Although the species composition of the sites on the Central Plateau was the same (apart from the absence of *Orchestiella neambulans* at Butlers Road), relative abundance varied.

The pattern of captures over months (figs 2 & 3) was generally correlated for different species in the same site or area (table 2). *Mysticotalitrus tasmaniae* monthly captures were not correlated at Hornes Dam and D'Arcys Bluff (table 3). *Keratroides vulgaris* monthly captures were correlated at different sites on the Central Plateau, but these were not correlated with those obtained at Old Chum Dam (table 3). During October, most species at the Central Plateau sites showed a dramatic increase in captures that was not exhibited by amphipods at Old Chum Dam. Amphipods at the Central Plateau sites also showed proportionally greater capture rates in autumn and a less obvious peak in summer.

TABLE 1
Capture rate and percentage of total captures for amphipods at Old Chum Dam and the Central Plateau

Species	Central Plateau Sites						Old Chum Dam	
	Butlers Road		Hornes Dam		D'Arcys Bluff			
Keratroides vulgaris	114*	(91.5)†	213	(85.8)	927	(86.8)	199	(99.1)
K. angulosus	–		–		–		1.8	(0.9)
Mysticotalitrus tasmaniae	2.6	(2.1)	21	(8.4)	30.4	(2.8)	–	
M. cryptus	7.7	(6.2)	3.4	(1.4)	109	(10.2)	–	
Neorchestia plicibrancha	0.3	(0.2)	8.6	(3.5)	0.3	(0.03)	–	
Orchestiella neambulans	0	(0)	2.2	(0.9)	1.4	(0.1)	–	
Total captures	439		1949		7487		4002	
Number of pits/7 nights	352		787		701		1993	

* Capture rates are expressed as numbers per 100 pits, calculated from pitfall trapping for seven days each month for a 12-month period.
† Percentage of total captures.

TABLE 2
Correlation coefficients for captures of different species* in the same sites

Species comparison	r	p
Hornes Dam		
K. vulgaris vs *M. tasmaniae*	0.84	<0.001
K. vulgaris vs *N. plicibrancha*	0.91	<0.001
M. tasmaniae vs *N. plicibrancha*	0.73	<0.01
D'Arcys Bluff		
K. vulgaris vs *M. tasmaniae*	0.78	<0.01
K. vulgaris vs *M. cryptus*	0.60	p<0.05
M. tasmaniae vs *M. cryptus*	0.31	N.S.
Old Chum Dam		
K. vulgaris vs *K. angulosus*	0.81	p<0.01

* Only those pairs of species with sufficient numbers for analysis were included.

TABLE 3
Correlation coefficients for captures of the same species in different sites and areas

Area comparison	*Keratroides vulgaris*		*Mysticotalitrus tasmaniae*	
	r	p	r	p
Butlers Road vs Hornes Dam	0.88	<0.001	–	–
Butlers Road vs D'Arcys Bluff	0.75	<0.01		–
Hornes Dam vs D'Arcys Bluff	0.69	<0.05	0.36	N.S.
Central Plateau vs Old Chum Dam	0.45	N.S.	–	–

TABLE 4
Correlations between captures of amphipods and mean temperatures

Species/sites	Min. temperature		Max. temperature	
	r	p	r	p
Keratroides vulgaris				
Central Plateau				
D'Arcys Bluff	0.59	<0.05	0.54	N.S.
Hornes Dam	0.83	<0.001	0.66	<0.05
Butlers Road	0.86	<0.001	0.70	<0.005
Old Chum Dam	0.87	<0.001	0.95	<0.001
Mysticotalitrus tasmaniae				
Hornes Dam	0.67	<0.05	0.62	<0.05
Neorchestia plicibrancha				
Hornes Dam	0.61	<0.05	0.52	N. S.

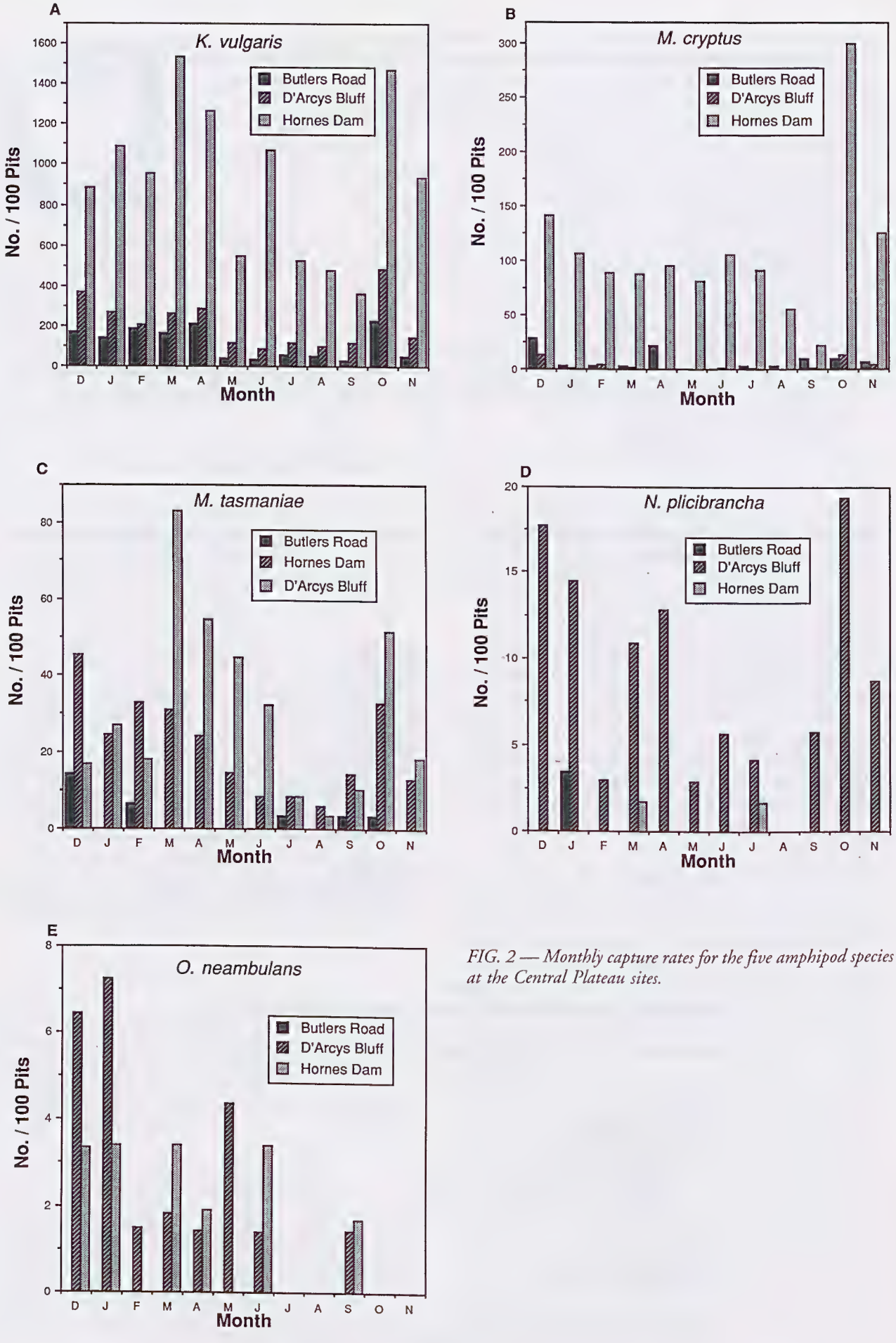

FIG. 2 — Monthly capture rates for the five amphipod species at the Central Plateau sites.

At the Central Plateau sites minimum temperatures were lower and rainfall was higher than at Old Chum Dam (figs 4 & 5). Only a few species were captured frequently enough to allow a multiple regression analysis of the influence of climatic variables on capture rates. At the Central Plateau sites, minimum temperature was consistently most highly correlated with capture rate, while at Old Chum Dam maximum temperature was most strongly correlated with capture rates (table 4). Temperature was more highly correlated with capture rates at Old Chum Dam than at the Central Plateau sites. Addition of rainfall variables (total rainfall and number of raindays, both during and for seven days prior to trapping) did not add significantly to the explanation of variation in capture rates. The rate of change in captures with changes in minimum temperature did not differ significantly (analysis of covariance, $F_{(1,20)} = 1.3$) between populations of *K. vulgaris* at the Central Plateau and at Old Chum Dam.

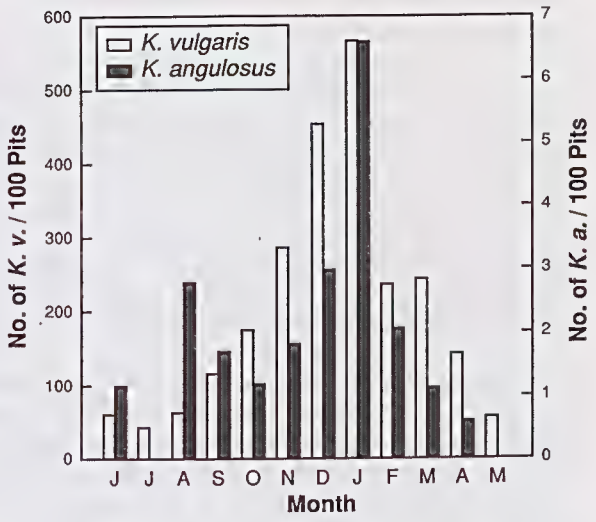

FIG. 3 — Monthly capture rates for amphipod species at Old Chum Dam.

DISCUSSION

The capture rate of amphipods in the pitfall traps is probably a reflection of both activity levels and population size. Studies have shown that population size of terrestrial amhpipods, measured by sampling individuals directly from the litter and soil, changed during the year (Duncan 1969, Tamura & Koseki 1974), and that these changes were due to seasonal reproductive patterns. In New Zealand forests, McColl (1975) found that changes in temperature over the period of a year correlated with capture rates of amphipods. However, in their study of an amphipod community in southwestern Tasmania dominated by *Austrotroides maritimus*, Richardson *et al.* (1991) found no change in capture rate over a ten-day period in summer, despite the passage of a cold front that brought a noticeable change in the weather. The differences between these two studies suggest that capture rates may be more influenced by population density than by activity levels. The chance of capture probably increases with body size within a species, and, hence, the age structure of the populations may also have influenced the results.

Since the traps were open for about a quarter of the year, it is possible that trapping could have led to depletion of populations around trap sites. However, there is no such trend apparent in the data, apart from the relatively immobile *Orchestiella neambulans* (fig. 2E).

The capture rates of amphipods were found to be most influenced by temperature. In the colder sites at the Central Plateau, where temperatures during the year range between –2° and 19°C, amphipod captures were more closely correlated with minimum rather than maximum temperature, whereas the reverse was the case at the warmer area at Old Chum Dam. The more open vegetation at Old Chum Dam probably allows penetration of sunlight to the ground surface to a greater extent than at the Central Plateau sites, where a dense secondary tree layer or shrub layer often shades the ground. Litter temperatures at night

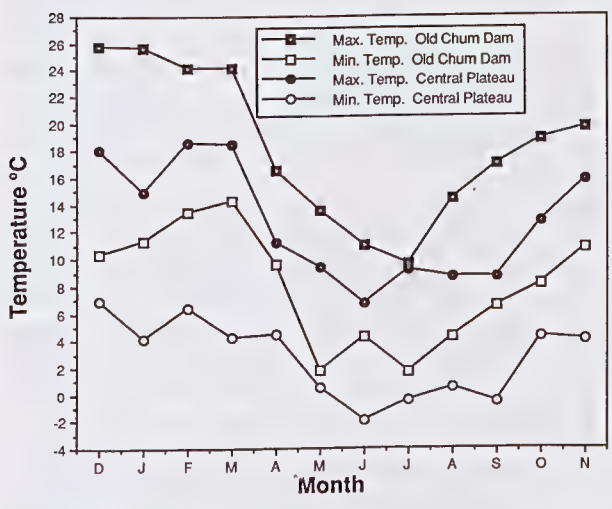
Max. Temp. Old Chum Dam
Min. Temp. Old Chum Dam
Max. Temp. Central Plateau
Min. Temp. Central Plateau
Temperature °C
Month
D J F M A M J J A S O N

FIG. 4 — Mean temperatures for the study areas during the census periods.

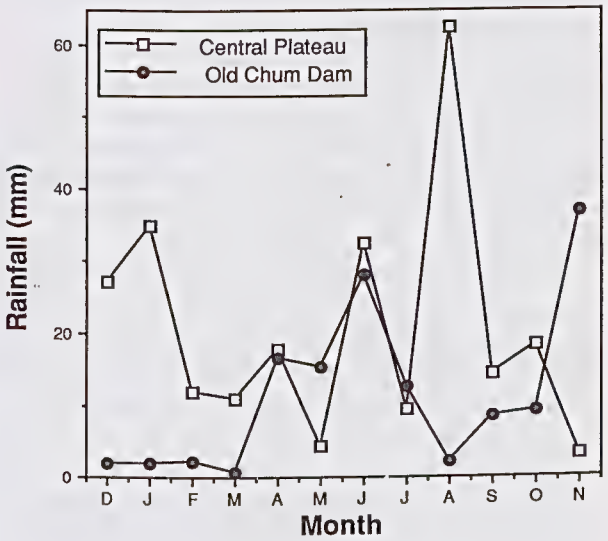

FIG. 5 — Rainfall (mm/7 days/month) at the study areas during the census periods.

at Old Chum Dam, thus, may follow maximum temperature more closely, particularly as frosts are rare. At a site in eastern Tasmania with a mild climate similar to that at Old Chum Dam, Friend & Richardson (1977) showed that on a cold day in autumn soil and litter temperatures at night stayed warmer than air temperatures, but on a warm day overnight soil and litter temperatures were similar to air temperatures. McColl (1975) also found minimum temperature to be correlated with monthly captures of amphipods in a wet *Nothofagus* forest in New Zealand.

Neorchestia plicibrancha, Mysticotalitrus cryptus and, to a lesser extent, *M. tasmaniae* and *Keratroides vulgaris* all showed a large increase in capture rates in October at the Central Plateau sites. Such an increase was much larger than expected on the basis of temperatures for that month. However, there was a large increase in temperatures between September and October, and this flush of captures coincided with a return to warmer spring conditions. Perhaps favourable moisture conditions which remained from the heavy rain in August (fig. 5) acted in concert with the increasing temperatures to produce the peak in activity. Alternatively, the higher capture rates could be related to reproductive activity, with a greater mobility of males and/or a flush of juveniles at this time. If this is correct, it implies a difference in the timing of breeding between the Central Plateau and the Old Chum Dam populations. *Mysticotalitrus tasmaniae* and *K. vulgaris* at D'Arcys Bluff also exhibited relatively high captures in March and April, before the fall in minimum temperatures to the colder autumn/winter period (fig. 4). Such a pattern is not totally explained by temperature, as temperatures were higher in February but capture rates were substantially lower.

The composition of the amphipod fauna at Old Chum Dam is the same as that found by Friend & Richardson (1977) at a site in eastern Tasmania, where *K. vulgaris* and *K. angulosus* differed in their vertical distribution, with *K. angulosus* occurring deeper in the soil/litter profile (at least for part of the time) and *K. vulgaris* engaging in longer periods of intense activity in laboratory trials. Both these characteristics make *K. vulgaris* more susceptible to capture in pitfall traps. Therefore, the differences in abundance of *K. vulgaris* and *K. angulosus* at Old Chum Dam are likely to be less than indicated by capture rates.

At the Central Plateau sites more species were captured, despite a smaller area being trapped with fewer pitfalls, and abundance at two of these sites was also greater than at Old Chum Dam. This difference may be related to biogeographic factors, in that more species are present in western than in eastern Tasmania. However, ecological factors may also be involved. There is a greater development of the litter habitat at the Central Plateau sites, due to the higher biomass of vegetation and the lower frequency of fires. The lower temperatures may also reduce the decomposition rates of litter. Additionally, higher rainfall and the greater shading of the litter at the Central Plateau sites may favour amphipods, due to their preference for moist, humid environments. The greater development of litter at the Central Plateau may allow greater partitioning of habitat space, which is probably a limiting resource (Friend & Richardson 1986). Species may also subdivide habitat on the basis of their water regimes, with some species preferring moist gully bottoms (Richardson & Devitt 1984, Friend & Richardson 1986). The three most abundant species at the Central Plateau site were the same species found by Richardson & Devitt (1984) in wet forest below 1000 m on Mt Wellington in southeastern Tasmania. Richardson & Devitt (1984) found differences in the relative abundance of the species at different locations across a gully and vertical separation of *K. vulgaris* and *M. tasmaniae*, with *M. tasmaniae* being more active in the upper layers and on the litter surface.

Neorchestia plicibrancha was also recorded by Richardson & Devitt (1984) on Mt Wellington, but it was very restricted, occurring between 1000 and 1200 m in the coolest, most shaded sites. *Neorchestia plicibrancha* was also uncommon on our study sites. However, this species is very common in rainforest in the west (A. Richardson, pers. comm.). The other rarely captured species, *O. neambulans*, was found on only two of the Central Plateau sites and represented 0.3% of the catch at these sites.

This study found that temperature was most influential in determining capture rates of amphipods at the surface of the litter. It was expected that moisture would also influence capture rates. However, no evidence for this was found, possibly due to our lack of a litter moisture index as opposed to simple rainfall statistics. Moisture is certainly influential in determining distribution of species within a site and the cooler, wetter sites with a higher vegetation cover on the Central Plateau were more species rich and usually supported a higher abundance of amphipods than the warmer, drier area in northeasternTasmania.

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THE MOUNT WELLINGTON STRING BOG, TASMANIA

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(with four text figures)

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A string bog ecosystem occupies part of a subalpine valley on Mt Wellington, Tasmania. The steps in the subsurface blockstream preferentially underlie pools. Variations in pool hydrology are independent of pool size. There is a correlation between pool shape and pool type, an oval shape being indicative of more recent secondary pool formation, primary pools with rocky floors being variably shaped. Variation in the bog vegetation is closely related to variations in slope, drainage and peat depth. The major changes in abundance of pollen types are related to changes in abundance of charcoal. The Mt Wellington string bog complex appears likely to have been formed by similar processes to those postulated to have resulted in the string bog system at Mt Field.

Key Words: string bogs, morphology, hydrology, vegetation, pollen, Tasmania.

INTRODUCTION

String bogs are common in polar and boreal regions. They have been defined as "areas of peatland characterized by ridges of peat and vegetation, interspersed with depressions that often contain shallow ponds" (Washburn 1979: 174). The ridges, or strings, can be up to two metres in height and may be tens of metres long (Gore 1983). Patterned peatlands, resembling string bogs, in Kosciusko National Park, New South Wales, were described by McElroy (1951) and Costin *et al.* (1979). Millington (1954) described a *Sphagnum* hummock–hollow regeneration complex in northeastern New South Wales. In Tasmania, Martin (1940) and Jackson (1973) noted the existence of features resembling string bogs on Mt Wellington and the Central Plateau respectively, and there have been recent detailed investigation of the dynamics of a bolster heath string bog at Newdegate Pass, Mt Field (Kirkpatrick & Gibson 1984, Gibson & Kirkpatrick 1992).

Most studies of string bogs have focussed on developing and validating hypotheses related to their origin and development (Walter 1977). These hypotheses vary in their recourse to biotic, gravitational and periglacial processes. However, the evidence from different parts of the globe tends to suggest that the string bog landform is distinctly multigenetic (Moore & Bellamy 1974). In Tasmania, Kirkpatrick & Gibson (1984) argued that the Newdegate Pass string bogs (which are approximately 60 km WNW of Mt Wellington) had developed on an underlying stepped block stream by differential growth of bolster plants in response to drainage diversions created by their initial establishment. They observed that ponds tended to drain by tunnel erosion after their dams exceeded a certain height, and that new dams began to form in the rocky bottom of the old ponds. They suggested that pond drainage was most rapid where overland flow was greatest. Kirkpatrick & Gibson (1984) concluded that, although there were cyclic elements in the history of the bog, any rapid short-term changes were necessarily degradational. Their conclusions were largely based on surface and subsurface morphology. The string bog on Mount Wellington (fig. 1) is morphologically similar to that at Newdegate Pass, while having few higher plant species in common.

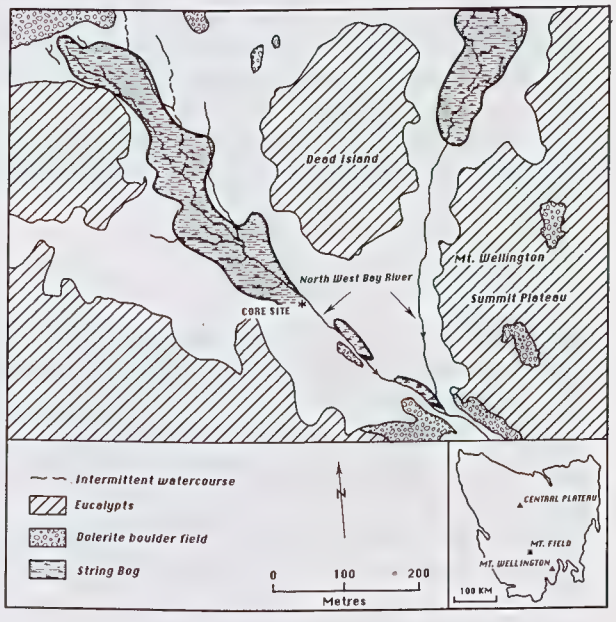

FIG. 1 — Location of ponds and streams on Mount Wellington.

The major aim of this paper is to describe and explain variation in the Mount Wellington string bogs, using quantitative data on vegetation, pool morphology and hydrology.

METHODS

Morphology and Hydrology

The surface topography was surveyed along a transect through the string bog sequence, using a dumpy level and Carr staff. The subsurface topography was measured on the lower part of the sequence at 1 m intervals, and at 0.5 m intervals on four transects radiating out from each of 20 intensively studied pools. Peat depth was determined by inserting a 2 m long metal rod through the peat until rock or gritty clay prevented further penetration. Step length was measured along the long transect by taking a distance between the top of a protuberance in the subsurface topography and the next upslope point at the same altitude.

Twenty pools were selected for hydrologic investigations on the basis of the following criteria: they appeared unlikely to dry out during the summer (to facilitate comparable measurements); they represented a range of sizes and depths; they varied in their location in relation to the main drainage lines. Water depth was measured on reference poles 17 times over seven weeks during summer. A pit 0.3 m × 0.3 m × 0.5 m was dug beside the pool furthest upstream to measure fluctuations in the water table. A Bureau of Meteorology rain gauge was placed in the bog. Rainfall and water-table height were recorded at the same time as water depth.

Eighty other pools were also investigated. They were selected randomly in the field and measured in order to assess variations in size of pools, variations in water depth, shape and rockiness of pools, and dam wall and aquatic vegetation. This information was tabulated with similar information from the 20 selected pools, to give an indication of the range of physical properties of pools in the string bog complex.

Vegetation

Four quadrats, measuring 2 m × 1 m, were laid out at points north, east, south and west of each of the 20 selected pools. Quadrat size was determined by constructing species area curves (Mueller-Dombois & Ellenberg 1974). These quadrats were located as near as possible to the longest/broadest points of the pools. The pool wall was used as the quadrat boundary with aquatic vegetation being excluded.

Species cover-abundance was noted, using the Braun-Blanquet system (Mueller-Dombois & Ellenberg 1974). Where possible, plants were identified to species level. Species nomenclature follows Buchanan *et al.* 1989.

The quadrat species cover codes were used as the input to a polythetic divisive classification using TWINSPAN (Hill 1979). Chi-square was used to test the significance of associations between floristic communities and environmental variables.

Palynology and stratigraphy

A Livingstone corer was used to extract an 0. 74 m core, which compressed to 0.51 m during extraction. The core site is located approximately in the centre of the northern mire complex in a flat area immediately in front of a pool wall (Whinam 1985). The vegetation at the core site is dominated by *Empodisma minus*, with *Poa gunnii*, *Craspedia alpina*, *Helichrysum backhousii* var. *oreophila*, *Olearia algida*, *Helichrysum scorpioides* and *Acaena montana* also present.

Three pollen samples were taken from the surface of the peat 10 m, 20 m and 40 m from the site of the extracted core. These were counted and analysed to provide a modern-day pollen analogue for interpretation of the core (Rymer 1978, Caseldine 1981).

The core sampling interval was 0.1 m, with a few intermediate samples at 0.05 m intervals. The samples were leached with HCl and processed using the method of Faegri & Iversen (1975). The samples were stained with safranin and mounted in glycerol. Exotic *Lycopodium* spores were inserted into the pollen sample before treatment to allow measurement of the concentration of pollen (Stockmarr 1971).

The slides were systematically scanned with a Wild binocular microscope on × 200 magnification, with × 400 magnification being used to identify initial and problem pollen. Pollen and spores were checked against the reference collection in the Department of Geography and Environmental Studies, University of Tasmania. The results are based on a minimum pollen sum of 300 grains, with an average count of 419 grains/spores at each interval sampled. Carbonised particle concentrations were estimated by counting all carbonised particles greater than 20 microns and calculating relative and absolute numbers as a percentage of the pollen sum (Hope & Peterson 1976).

RESULTS AND DISCUSSION

Bog morphology and hydrology

The string bogs are located in the headwaters of the North West Bay River (fig. 1). The general slope of the western part of the bog varied from 2.1° to 3.6° The mean area of pools was 25.33 m^2 (n = 100, s.d. = 30.9 m^2, range = 0.3–170m^2), with a mean maximum depth of 0.54 m (s.d. = 0.23 m, range = 0.18–1.10 m^2). Fourteen of the hundred pools had a peat base. The rest had floors composed of rocks and organic detritus with the relative area of peat floor being variable, but being on average 60%. Although aquatic vegetation cover was generally negligible, only 13 of the pools lacked any higher plants, while 71% contained aquatic *Isolepis* spp. and 52% contained *Myriophyllum pedunculatum*. The only other vascular plant found in the pools was *Ranunculus glabrifolius* (3%).

Forty per cent of the pools were elongate or oval, with the long axis along the contour, 26% were tear-drop shaped, the remainder being irregular in shape. Oval ponds had significantly more peat floors than could be expected by chance (chi-square = 14.3, d.f. = 2, $P < 0.001$). The ponds proved to be preferentially located on steps in the underlying boulder stream (fig. 2). Pools are preferentially located on step lengths >2.5 m (chi-square = 6, d.f. = 2, $P < 0.05$). All the steps without pools were 2.5 m or less in extent. Peat depth measurements taken on two axes across the pools and 2 m either side indicate that there is often a tall boulder underlying the front of the dam, a phenomenon also observed at Newdegate Pass (Kirkpatrick & Gibson 1984). The water levels in the 20 ponds and the ground water pit fluctuated in unison (fig. 3). There was no relationship between the size of the pond and the amplitude of fluctuations (fig. 3). The fluctuations were related to rainfall events (fig. 3).

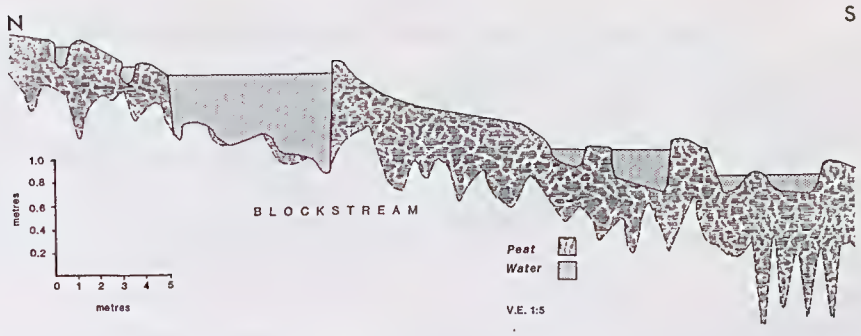

FIG. 2 — A cross-section of part of the northern string bog.

Vegetation

Most of the bog was burned in the severe 1967 bushfires, including all the sampled quadrats. Fires have played a major role in maintaining the seral nature of the vegetation on Mount Wellington with severe fires being recorded this century in 1900, 1924, 1939, 1947, 1965 and 1967 (Ratkowsky & Ratkowsky 1976, 1977). Small unburned areas are dominated by 1 m tall shrubs, mostly *Richea scoparia* and *Orites acicularis*. The burned part of the bog consists of a tall, alpine herbfield (*sensu* Kirkpatrick 1983), dominated by either *Astelia alpina* or *Empodisma minus* with occasional emergent composite shrubs (*Helichrysum hookeri, H. backhousei, Olearia algida* and *O. obcordata*). Seedlings of *Richea scoparia, R. gunnii* and *Orites acicularis* are present in sufficient density to eventually form closed heath. *Astelia alpina* tends to be more prominent along streams and on the margins of ponds than in the interstices between these features, where *Empodisma* usually dominates.

Sphagnum commonly dominates in string bogs in areas with uniformly cool, moist climates (for example, northern Europe). In Tasmania, as in New Zealand, other species, such as *Empodisma minus* and *Astelia alpina,* are active peat producers (Campbell 1983). *Sphagnum* is localised in its occurrence in the Mt Wellington string bogs.

The taxa with high constancy throughout the bog are *Helichrysum hookeri, Astelia alpina, Olearia algida, Empodisma minus, Poa gunnii, Craspedia alpina, Epacris serpyllifolia* and *Carex* sp. (table 1). The TWINSPAN sorted table contained four moderately distinct floristic groups: group 1 is characterised by the presence of *Drosera arcturi, Sphagnum cristatum* and *Euphrasia collina*; group 2 has low representation of the above species, but shares with group 1 a high frequently of *Gleichenia alpina* and an absence of the species that characterise groups 3 and 4; group 3 is best characterised by high frequencies of *Uncinia compacta* and *Celmisia asteliifolia;* group 4 is best characterised by *Helichrysum rutidolepis* and *Hierochloe redolens* (table 1).

The distributions of the floristic communities are strongly related to slope (chi-square = 43.6, d.f. = 6, $P < 0.001$), with communities 4 and 3 being twice as common as expected on the very gentle slopes (<2°), community 1 being twice as common as expected on the gentle slopes (2–6°) and community 2 being one and half times as common as expected on the moderate slopes (>6°). Community 4 is also preferentially located on the downslope walls of ponds (chi-square = 15.7, d.f. = 1, $P < 0.001$), whereas community 3 is preferentially located away from the edge of ponds (chi-square = 37, d.f. = 1, $P < 0.001$). Community 1 occurs less than half the times that could be expected around ponds

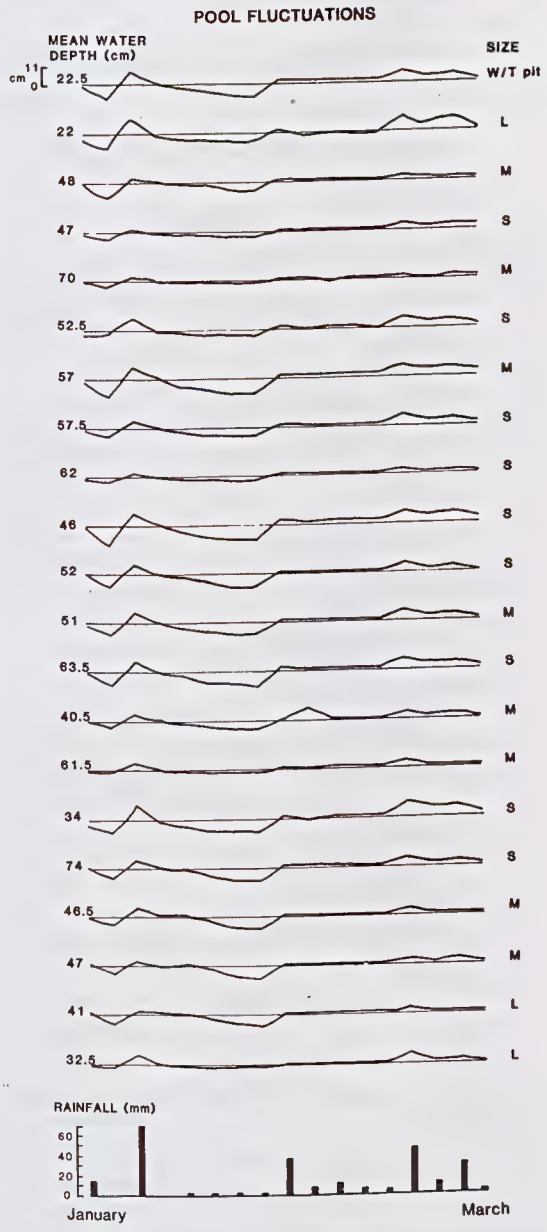

FIG. 3 — Fluctuations in the water level of pools and the watertable (W/T) pit and incidences of rainfall. S = small (< 10 m²), M = medium (10–50 m²), L = large (> 50 m²). Pools are in order, down the string bog sequence.

with low water-level amplitudes (chi-square = 2.92, d.f. = 1, $P < 0.05$). The cover ratio *Empodisma/Astelia* is greatest for community 3 and differs little between the other

TABLE 1
Percentage frequency of most frequent taxa by classificatory group

	TWINSPAN group			
	1	2	3	4
No. of quadrats	17	28	13	30
Drosera arcturi	71	–	8	–
Sphagnum australe	76	3	–	–
Myriophyllum pedunculatum	29	–	–	–
Ourisia integrifolia	35	–	8	3
Ranunculus glabrifolius	29	–	8	6
Gentianella diemensis	18	–	8	–
Bellendena montana	12	7	8	–
Baeckea gunniana	47	18	15	3
Helichrysum backhousii var. *backhousii*	65	25	46	3
Euphrasia collina ssp.*diemenica*	71	14	62	37
Gleichenia alpina	94	89	8	7
Richea gunnii	65	46	38	13
Oreobolus spp.	29	11	15	27
Epacris serpyllifolia	100	86	45	63
Carex sp.	88	82	–	37
Craspedia alpina	100	89	92	93
Poa gunnii	94	82	92	96
Empodisma minus	100	89	100	100
Olearia algida	94	86	69	80
Astelia alpina	88	71	69	97
Helichrysum hookeri	65	82	69	80
Luzula sp.	11	–	–	–
Orites acicularis	11	–	8	–
Uncinia compacta	–	4	100	16
Celmisia asteliifolia	29	18	54	7
Carpha alpina	6	11	15	7
Helichrysum backhousei var. *oreophilum*	12	43	92	90
Sphagnum cristatum	18	4	69	40
Danthonia sp.	–	–	15	–
Helichrysum rutidolepis	18	4	46	70
Acaena montana	6	–	46	47
Olearia obcordata	6	–	54	47
Asperula gunnii	12	14	8	40
Hierochloe redolens	6	4	–	53
Richea scoparia	–	21	16	27
Helichrysum ledifolium	–	–	–	13
Epilobium sp.	–	–	–	7

communities, although the greatest cover of *Astelia* is in community 4.

As all of the bog is constantly moist, the distribution of species and communities cannot be related to variations in site dryness. However, the above analyses do imply a strong differentiating role for soil aeration. Thus, community 4 occurs preferentially on dam walls and around ponds with large water fluctuations. Good aeration allows for high overlapping cover, and this high cover excludes many of the smaller taxa common in community 3, which occurs between the ponds and on the walls of ponds with low amplitudes. Community 2 occurs beside pools on the steeper slopes, where aeration would be generally better than on gentler slopes. Community 1 differs from community 2 only in its possession of a group of species usually associated with standing water, and its predilection for pools on slightly gentler slopes.

Vegetation history

Absolute and relative pollen diagrams and charcoal and pollen and spore concentrations are shown in figure 4. The pollen taxa that constitute most of the count fall into three distinct classes of stratigraphic pattern: (1) Gramineae (Poaceae) pollen numbers decline from 0.5 to 0.2 m in

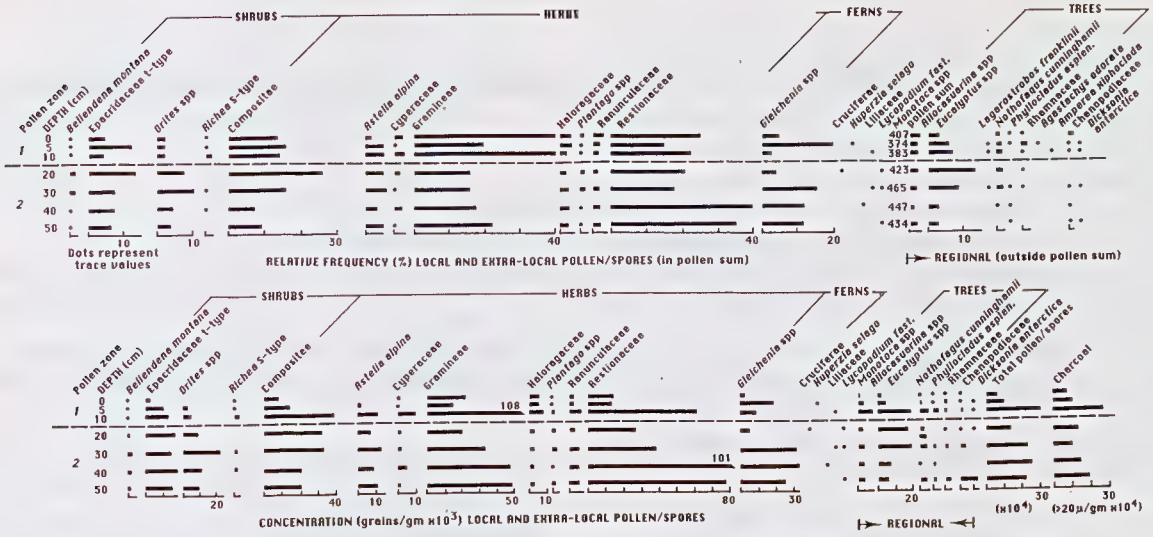

FIG. 4 — Absolute and relative pollen diagrams, with charcoal, pollen and spore concentrations.

zone 1 and then increase in zone 2; Restionaceae pollen shows a decline from the high values at 0.4 m; (2) *Astelia*, Haloragaceae and Ranunculaceae vary little in their abundance; (3) Copositae (Asteraceae), Epacridaceae (T-type), and *Orites* show a decrease in numbers from zone 1 to zone 2. The charcoal counts are positively related to Gramineae pollen concentration (Spearmans $r = 0.83$, $p < 0.05$).

The above data are consistent with a history of declining (zone 1) and then increasing (zone 2) fire frequency on the Mt Wellington bogs, as the Gramineae increase their cover after fire, *Orites acicularis* and many Epacridaceae species take many decades to recover their cover, while *Astelia* remains constant in cover (Kirkpatrick & Dickinson 1984). The spatial patterning of *Astelia* and Restionaceae (*Restio* and *Empodisma*) suggested that *Astelia* might be more important than Restionaceae in the early stages of dam formation. However, there is no indication of this phenomenon in figure 4.

Several features of the bog and the core suggest a mid-Holocene origin for the string bog. The absence of the early Holocene *Pomaderris* peak (Macphail & Jackson 1978; Macphail 1979; Thomas 1984) on a *Pomaderris*-rich mountain (Martin 1940), in combination with the other bog characteristics, such as peat depth, extent of the deposit and vegetation history, strongly suggest an age of less than a few thousand years. Such an age would be consistent with the conclusions of Caine (1983) and Macphail & Hope (1985), who suggest that there has been a marked resurgence in bog growth after c. 3500 BP. However, reservations have been expressed about this putative resurgence (Young 1986).

General Discussion

The Mt Wellington mire in strict definition is a mildly acidic, minerotrophic fen. This string bog sequence is probably close to the climate margin for such formations (Barber 1981, Moore & Bellamy 1974, Young 1983). The annual average minimum temperature is 1.1°C and the average maximum temperature is 7.3°C. Average annual precipitation is approximately 1250 mm (Macphail & Peterson 1975). The hummocks and flarks associated with string bogs are only poorly developed, compared to sequences in the Northern Hemisphere. Thus, the pools are both fewer and smaller on Mt Wellington than in string bogs in the Northern Hemisphere reported in the literature, and the strings or ridges are less elongate. However, the surface and subsurface topography, vegetation and surficial features at Mt Wellington resemble similar descriptions from Newdegate Pass, Tasmania (Kirkpatrick & Gibson 1984), the Central Plateau (Jackson 1972) and Arthur's River, New Zealand (Knox 1969), except that their microtopographic expression has been reduced by localised peat losses apparently due to firing of large bushes.

The broadscale surface and subsurface topography appear to be related, with the string bogs being "stepped", with a boulder often forming part of the dam wall. The large sizes of some pools away from major drainage lines suggest that these are stable pools which have existed for some time. Many of the dam walls of these pools are built up above the surrounding peat cover. Smaller pools along the main drainage channels appear to be less stable, with vegetation actively forming dams in some cases and collapse of dam walls being evident in others.

The significant number of large pools with rocky floor and no obvious depth of peat supports the supposition that these pools formed very early in the development of the sequence. The positive correlation of oval shape with ponds formed in peat with no obvious rocks supports the hypothesis that these are more recent, secondary formations (Birks 1972, Seppala & Koutaniemi 1985).

It is likely that fire has played a role in controlling the nature of the bog vegetation and has possibly impeded peat accumulation. The pollen record suggests a fairly stable subalpine fen vegetation throughout the development of the mire with some changes in dominance and relative species abundance. A simultaneous increase in charcoal and grass pollen, combined with the appearance of two *Pinus radiata* pollen (5 cm sample) in the pollen record, suggests that fire has increased since European settlement (Whinam 1985).

As geomorphic evidence suggests that mean annual temperatures were depressed by 6°–8°C during the Last Glacial (Kiernan 1983), and the mean temperature at the study site is 4.1°C today, it seems likely that the string bogs are Holocene in origin.

Warmer post-glacial temperatures would have allowed the development of vegetation on interstitial clays in the fossil blockstreams. As this vegetation decomposed, peat would have begun to form. Vegetation growing on this peat base would then be able to divert and redistribute surface flow, thus forming dams. Accumulation of peat would then have resulted in all but the largest boulders being covered, similar to the process proposed for Newdegate Pass (Kirkpatrick & Gibson 1984). Secondary pools could then form in micro-topographic hollows in the peat. The development of at least some of these hollows may have been related to fire damage.

The future of the bog may depend on fire frequency. Peat erosion is occurring at its lower and upper margins. If, as seems likely from the evidence of dead shrubs dating from 1967, their erosion is caused by firing, the bog will continue to retreat if fire is a frequent event.

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(accepted 16 February 1994)

HARDENBERGIA VIOLACEA (FABACEAE), IS IT NATIVE IN TASMANIA?

by A.M. Buchanan

(with one figure)

BUCHANAN, A.M., 1994 (30:vi): *Hardenbergia violacea* (Fabaceae), is it native in Tasmania? *Pap. Proc. R. Soc. Tasm.* 128: 69–70. ISSN 0080–4703. Tasmanian Herbarium, GPO Box 252C, Hobart, Tasmania, Australia 7001.

Hardenbergia violacea (Schneev.) Stearn is accepted as native in Tasmania.

Key Words: ***Hardenbergia violacea*, Tasmania, Augustus Oldfield.**

Hardenbergia violacea was first described (as *Glycine violacea*) by Schneevoogt (1793) from cultivated plants probably collected as seeds in the Sydney area in the first few years of settlement. This scrambling or trailing perennial grows from a woody rootstock and produces long wiry stems that climb on other plants or trail over rocky outcrops. It is well known in Victoria and New South Wales, where it occurs widely in dry open forests, but its occurrence in Tasmania is limited to the Pontos Hills near Richmond in the southeastern part of the state.

Some doubt has existed as to whether this plant is native in Tasmania. Curtis (1956) and Curtis & Morris (1975) considered that it may have been introduced, and Willis (1972) questioned its status in Tasmania. Its singular occurrence, far from the mainland, in a farming district that had been occupied since the earliest years of European settlement, tended to support the assumption that it had escaped from a local garden.

The first definite reference to the genus *Hardenbergia* in Tasmania was that of Hooker (1859), based on specimens collected about 1857 by Augustus Oldfield on "rocky hills, near Frogmore, Richmond". Frogmore was a large grazing property near the present village of Penna; much of it has since been subdivided into smaller holdings.

Following Oldfield's collection of last century, no further collections are known until A. Moscal rediscovered the site and, some years later, in 1981, collected flowering material. The plants and their habitat appeared to be natural. Lynch (1993) described the population and its rocky sandstone habitat and accepted the species as indigenous.

Further evidence for its being native in Tasmania has recently come to light in the form of a short account in an early newspaper (*Hobart Town Courier* 1834). Assistant Surveyor William Malcolm, of the Survey Department, had been working in what was called the Sweetwater tier of hills near Richmond and had discovered a vine-like plant, not previously known to him. The plant was compared with Lempriere's (1954) description of *Polygonum adpressum* or Macquarie Harbour Grape (now *Muehlenbeckia gunnii*), of which it was thought to be a new species, but appeared "to be of a drier and more rigid quality". The leaves were "more fibrous and of rather a lighter green" and were "heart-shaped", while those of Macquarie Harbour Grape were "winged" (fig. 1). Unfortunately, the plants were not in flower, depriving Malcolm of good diagnostic characters. However, the vegetative characters described, together with the locality, leave no doubt that this is the first record of *Hardenbergia violacea* in Tasmania. An early map by Surveyor Evans (1822) has the words "Sweet Water" printed in the position of the present Pontos Hills, making it clear that this is the area referred to.

It is possible that Oldfield, about 20 years later, knew of Malcolm's discovery, either through conversation or by reading the old newspaper account. In any event, his collections, forwarded to Joseph Hooker at Kew, England, established the identity of the plant as a *Hardenbergia*. Hooker received the specimens just in time to include a description in the "Additions, Corrections, etc." that he appended to his Flora shortly before publication in late December 1859.

Hooker, however, placed the Frogmore material in Bentham's (1837) *Hardenbergia ovata*; perhaps Schneevoogt's earlier publication of *Glycine violacea* was unknown to him. Bentham (1864), in the first Flora for the whole of Australia, included the material in his (1837)

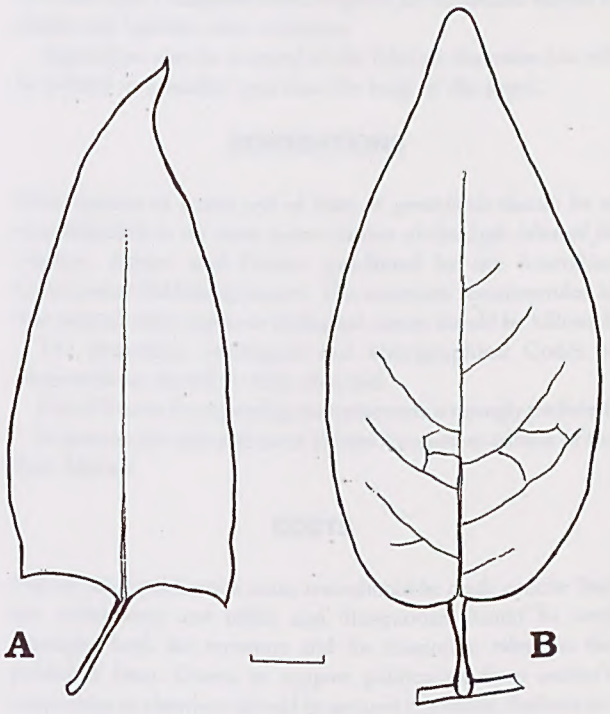

FIG. 1 — Typical leaves of (A) Muehlenbeckia gunnii *and (B)* Hardenbergia violacea *showing the hastate ("winged") base of the former and the cordate ("heart-shaped") base of the latter. Scale bar = 10 mm.*

H. monophylla. Rodway (1903), following Bentham, placed it in *H. monophylla* without commenting on its status. So far as can be judged, Rodway never saw the Frogmore plants; there are no specimens in his herbarium. It remained for Stearn (1940) to recognise Schneevoogt's *G. violacea* and its priority and to make the necessary new combination, *H. violacea*.

The discovery of this plant as early as 1834 provides good evidence for its being native in Tasmania, despite its highly disjunct distribution. Other plants with similarly disjunct distributions are *Calocephalus citreus* (Asteraceae), *Isoetopsis graminifolia* (Asteraceae), *Thesium australe* (Santalaceae), perhaps now extinct in Tasmania, *Pultenaea pedunculata* (Fabaceae) and *Eryngium ovinum* (Apiaceae). All are species of open, dry, warm habitats and were probably widespread in eastern Tasmania during the postglacial climatic optimum, but were later confined to the refugia in which we now find them.

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